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The Journal of HEREDITY

FINGER PRINTS OF IDENTICAL TWINS

Edward D. Metcalf—An Appreciation

A Chimera in the Fowl

The Drake Potato Monument

Twins Reared in City and Country

Chromosomal Types in Datura

VOLUME 20 APRIL, 1929 NUMBER 4

The American Genetic Association

An incorporated organization devoted to promoting a knowledge of the laws of heredity and their application to the improvement of plants, animals, and human racial stocks

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The

Journal of Heredity

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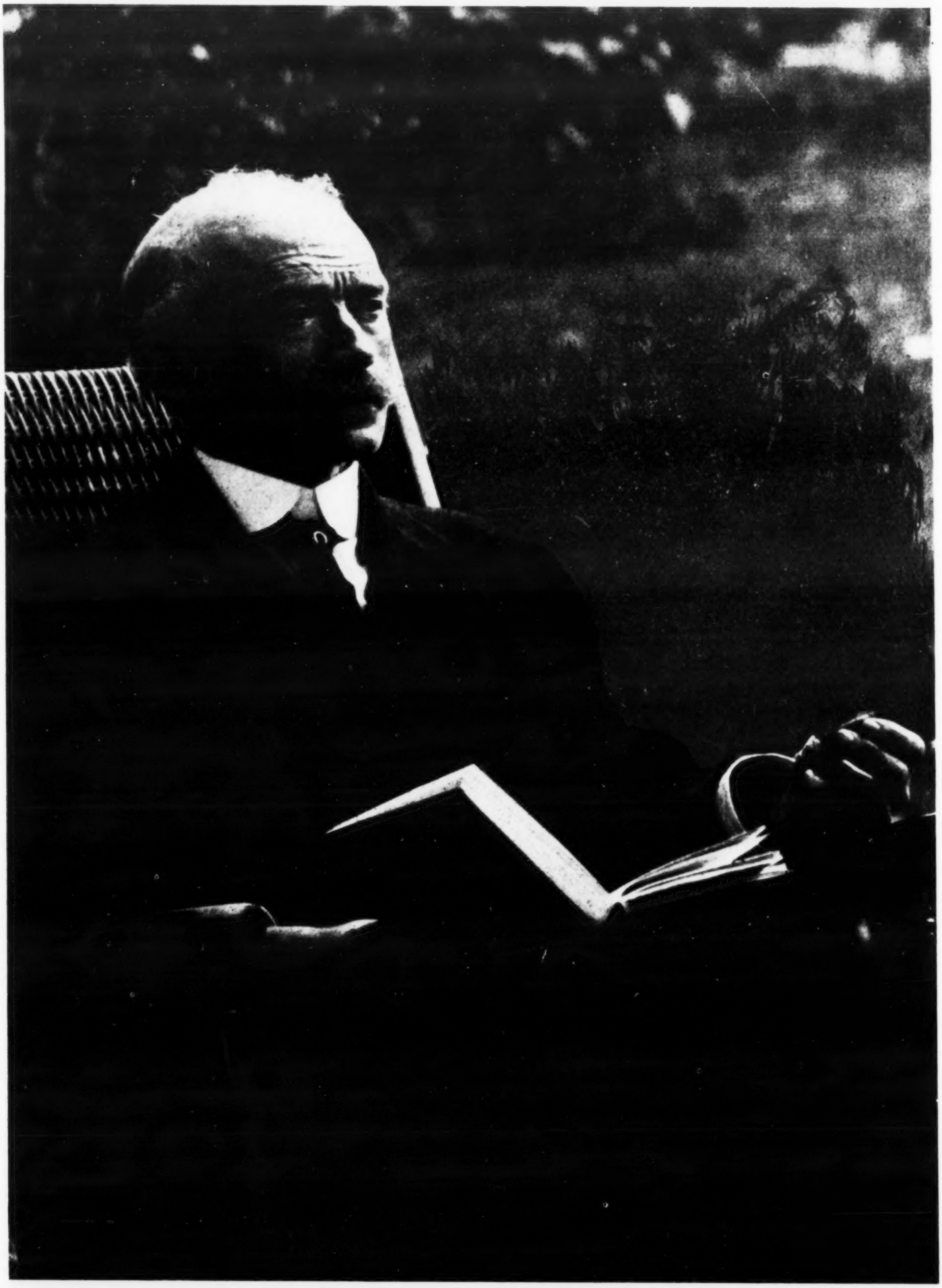


EDWARD DOUGLASS METCALF

Frontispiece

"What the world needs is a race of men who are neither crippled in body or mind; for when men are born right, they will have no need to be 'Born again' * * * Race betterment is the all-important work toward which our resources and energies should be directed and all other matters are significant only, or mainly, as they contribute to this grand purpose."

EDWARD D. METCALF

BURT GRIGGS
Buffalo, Wyoming

EDWARD DOUGLASS METCALF was born at Northfield, Vermont, January 20, 1859. Because of constitutional frailities, he was unable, as a youth, to enter into the sports of other boys of his age, by reason of which he developed a retiring disposition which was one of the characteristics of his later life. This inability to engage in strenuous exercise caused him to turn to books for recreation and companionship, with the result that he early acquired a fund of knowledge not possessed by others of his age.

Through his association with books he developed a curiosity for knowledge and first-hand information which later led him to extensive travels in strange places and foreign lands. When but nineteen years of age he shipped as a sailor before the mast on an old windjammer which took him on a two years' cruise around Cape Horn, thence to France and finally back to his own country. For months the ship was out of sight of land and the rough sea fare combined with the rigorous discipline of a hard shipmaster brought to the weakling boy a degree of health and strength never before enjoyed, but it also developed a wanderlust which remained with him until the end of his life.

Hardly had he returned from this rigorous voyage than the Western fever gripped him, and in 1880 he came to the Territory of Wyoming, arriving at Rock Creek on the Union Pacific, then the shipping point for Central and Northern Wyoming. Without money or friends, a stranger in a stern country, he started on the three-hundred-mile stage journey northward toward the town of Buffalo, soon to become his future home. After a stay of some weeks at Twenty-Mile Station on the old Ft. McKinney road, he finally arrived at Buffalo, then a hamlet of but a few souls, inhabited by the toughest element of the old West. Here he began at the lowest round of the ladder as a journeyman carpenter, and some of the buildings then constructed by his hands are still standing in the City of Buffalo as monuments to his skill and the honest materials used in their construction. Naturally a mechanic, it was a common statement that "Metcalf can do anything," and his fame as an all-around artisan brought him more work than he could do. The acceptance of employment meant to Mr. Metcalf an obligation to give the very best there was in him. No piece of work was ever slighted and never was unsound or unfit material used by him.

A Frontier Justice of the Peace

Buffalo at that time was one of the wildest of the old frontier towns. Located in the heart of the cow district of Wyoming within four miles of the old military post of Ft. McKinney, the town was overrun with soldiers, cowboys and refugees from all parts of the world. The Territorial Court convened but once a year, and in the intervals primitive justice was dispensed almost entirely by the frontier Justice of the Peace. Because of his superior education and attainments, the young carpenter was called to this thankless and rather perilous task and for several years his rough-and-ready decisions were accepted, without appeal, by the community. Never once was his honesty of purpose or fairness impugned. Many an incipient near-riot was quelled by the quiet young judge, whose word became law in a lawless country.

From carpenter and Justice of the

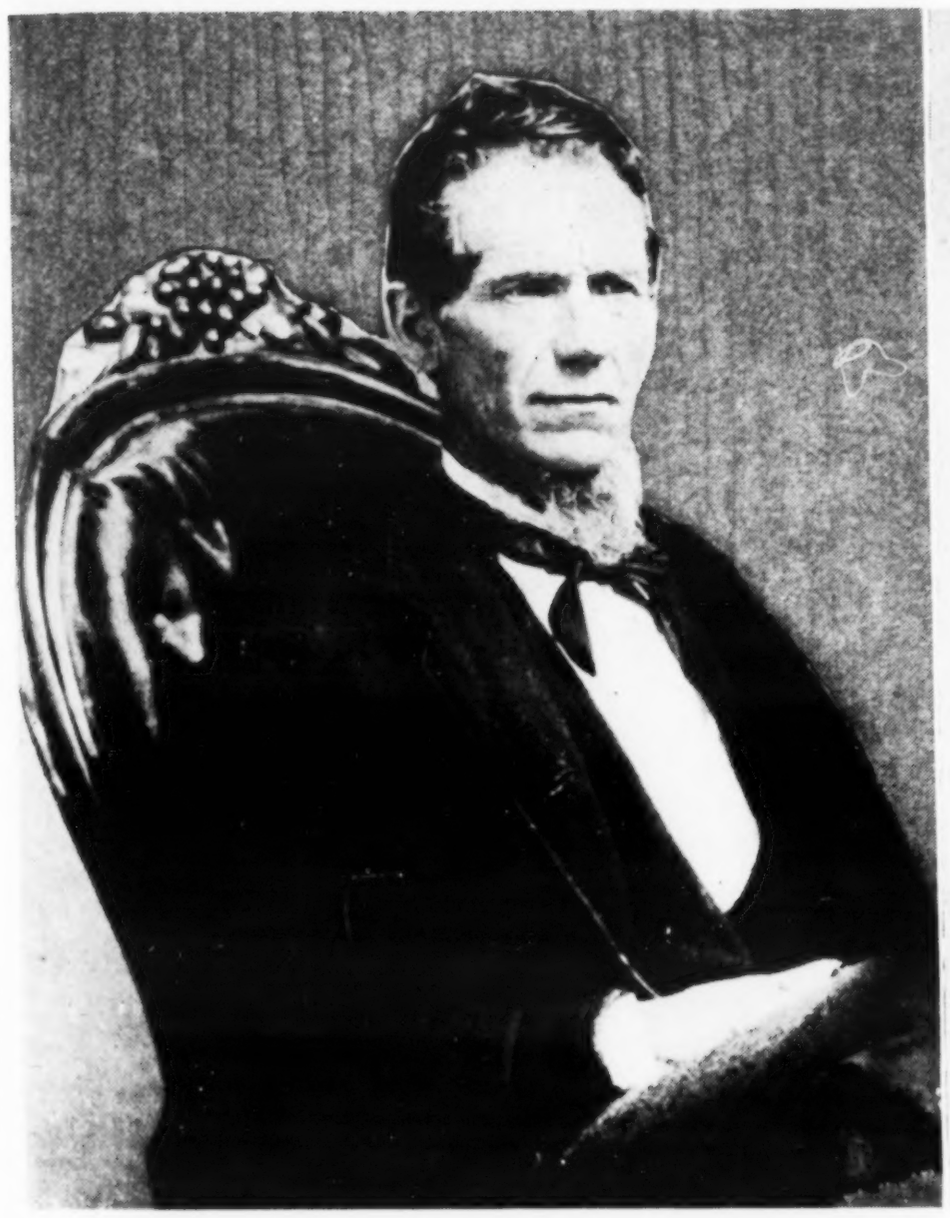
THE BOY AND THE MAN

Figure 1

The frail child was father to a man who spent an unusually strenuous and worthwhile life.

Peace to merchant was but a short step, and it was not long until the General Merchandise Store of E. D. Metcalf become a famous institution in Northern Wyoming. For many years Metcalf conducted the only grocery store in Buffalo and today the old-timers agree that never was the town better served either as to quality or price of merchandise than during the period when E. D. Metcalf had no competition. As a merchant, Mr. Metcalf established a reputation for honesty and fair dealing seldom enjoyed by anyone. Never was the quality of the goods sacrificed for price and never was the price greater than the quality required. Scrupulously honest himself, he demanded similar treatment from others, and had small patience for those who through fraud or sharp practice attempted to secure an unfair advantage. It is said that Abraham Lincoln, when a merchant, walked a considerable distance to rectify a mistake made in a sale. He had nothing over Mr. Metcalf in that respect, for one of his old-time clerks recently reported that Mr. Metcalf once drove a distance of twelve miles with horse and buggy to return an overcharge of twenty cents. On the other hand, if it developed that the customer was the beneficiary of an error Mr. Metcalf was just as prompt to require full payment, irrespective of person or amount. At times he exercised an almost paternal supervision over his customers and frequently refused to sell merchandise of a certain quality when he knew that the station in life of the purchaser required something different.

Johnson County then, as now, was a live-stock country, and from merchant he drifted naturally into the stock business, and through industry and close application to work, soon accumulated flocks of sheep from which the major portion of his later fortune was derived. In the meantime his increasing prominence in the community called him into the banking business and he became a director and vice-president of the First National Bank



THE PARENTS OF E. D. METCALF

Figure 2

Mr. Metcalf's parents were both New Englanders. Through his mother, Martha Chadwick Metcalf, he traced to the Hinmans of Revolutionary and Mayflower days. His father's people came to Northern Vermont from Keene, N. H., and settled on a farm. Aaron Metcalf was a public spirited citizen of Northfield, where he held at times various offices. He built a business block in the town of Northfield, and at the time of his death owned other real estate. Aaron and Martha Metcalf had five children, of whom one died in infancy. The three boys, George, Edward and Fred, all were bitten with the Western fever; two of them went to Wyoming and the other to California; all prospered. The daughter, Eliza, had a talent for art, and after her marriage continued her studies at the Metropolitan Museum of Art in New York.

of Buffalo, Wyoming, which position he held at the time of his death.

A venture in which Mr. Metcalf took considerable pride was his connection with an irrigation enterprise known as the "Sahara Ditch". There were five people originally in this project, which was organized in 1904. The canal is about seventeen miles long, and is located in southern Johnson County. The land at that time was absolutely barren and there was not an acre under cultivation within twenty miles of it. The canal cost about $120,000, and was financed entirely by the five men mentioned above, out of their personal resources. It was a very daring undertaking and there was a good chance of considerable losses, but largely because of the confidence of the settlers in the builders every acre of the land was colonized and it is today one of the most beautiful garden spots in the entire state of Wyoming. Thousands of tons of hay and thousands of bushels of grain are produced annually and the "Sahara Ditch" has made possible the development of as nice a community as can be found anywhere. There are excellent schools, a community building, and some of the finest ranch homes in this county. The settlers are almost uniformly prosperous and some of them are altogether out of debt, notwithstanding that the project

THE METCALF HOMESTEAD AT NORTHFIELD, VT.

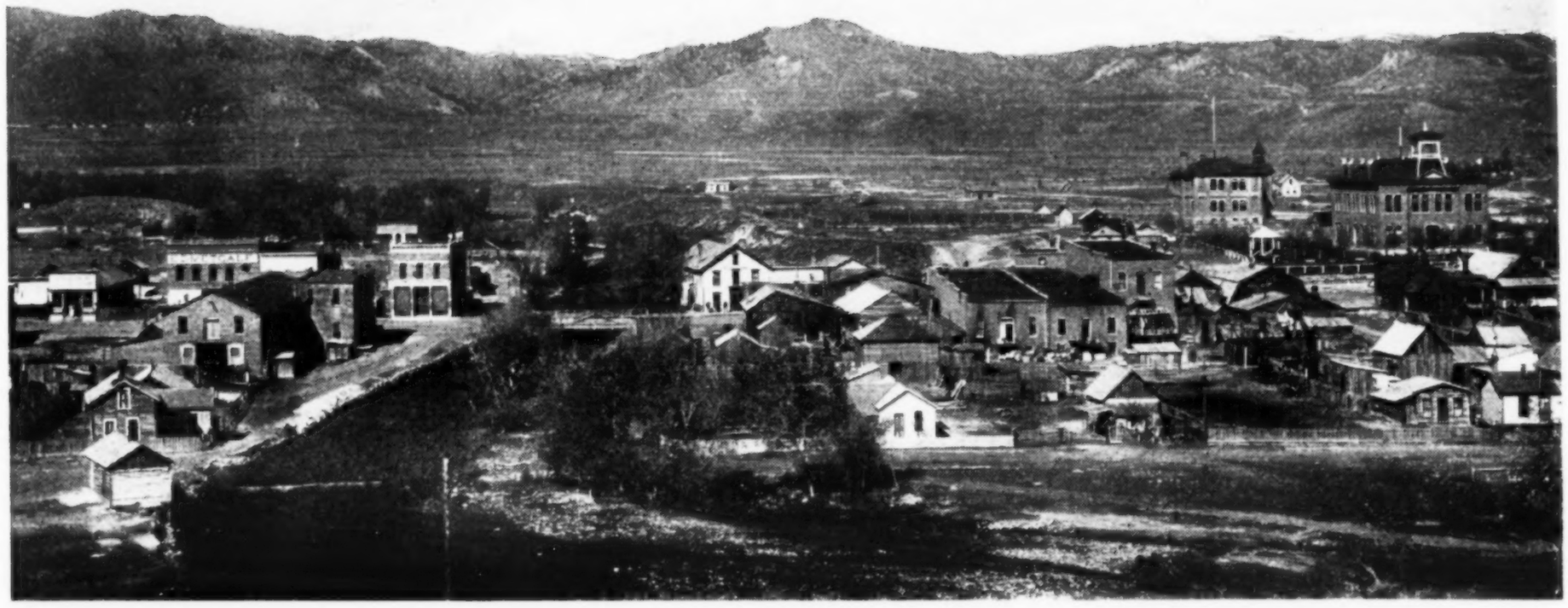
Figure 3

Mr. Metcalf's mother and sister are in the yard.

BUFFALO, WYOMING, IN THE 1880's

Figure 4

In the early history of the Northwest, Buffalo played an important and exciting part. Three hundred miles from the railroad, in the heart of the cattle country, and only four miles from Ft. McKinney, it was rated one of the wildest towns in the West. It was there that E. D. Metcalf served for years as Justice of the Peace, and on the right can be seen the old Metcalf store, a famous institution in Northern Wyoming.



BUFFALO ABOUT 1900
Figure 5

The school and the Court House are on the right. Fort McKinney can be seen at the left, in the middle distance. The establishment of E. D. Metcalf (on left) has grown considerably in the interval.

BUFFALO TODAY
Figure 6

Steam and gasoline have replaced the picturesque freight wagons; and over Southern Wyoming, where Metcalf took stage for Buffalo, the Air Mail drones its way through the night on the route of the Pony Express of seventy years ago. The hard life of those days made men. Today the main street of Buffalo is being linked by concrete and air into the endless Main Street that is America. As an experiment in human environment the rapidity of these changes has been unique. The results in terms of the effects on the race will form a fascinating and still indeterminate chapter in the history of the future.

was not completed until 1906 and was not entirely settled until 1910. If there ever was a case of making the desert bloom like a rose, it was this. It is worthy of note that this was all done without a single case of litigation and without serious dispute with any of the settlers. The builders recovered their original investment and a small amount of interest, a very unusual thing in ventures of this kind.

During the course of a busy and eventful career Mr. Metcalf's name became synonymous with equity and fair dealing. Always quiet, seldom mingling in the discussions of his fellow townsmen, he managed at all times to maintain a comprehensive grasp of local conditions probably unequaled by any other resident of the community. All matters brought to him received the most earnest consideration and attention and never was an opinion expressed until he was thoroughly convinced of its soundness. As a result his judgment was almost invariably accepted in the final settlement of mooted questions.

Soon after he entered the mercantile business, Mr. Metcalf met and married Miss Annie Elliot, a teacher in the Buffalo schools. Miss Elliot was a woman of rare intellectual attainments, of a high degree of education and active in matters of public welfare and improvement. Their home was one of culture and refinement, and, both being of a studious nature, they naturally retired into their well-chosen library, which was their mutual inspiration and recreation. Mr. Metcalf was a veritable mine of information on matters of science, history, astronomy and mechanics. His investigations were so extensive and thorough that there was scarcely a subject concerning which he was not fully informed. Any investigation undertaken was pursued until exhausted and nothing was too technical for him to undertake, yet so modest of his accomplishments and reticent in self-expression was he that not one in a dozen of his friends or acquaintances was aware of the profoundness of his knowledge or the depth of his intellect.

"For Service Rendered"

Early in his business career he adopted a philosophy of life which might well be termed the "Doctrine of Compensation". Briefly stated, it was his profound conviction that every one is entitled as a matter of right to that which he earns, and, conversely, a recipient of benefits is in duty bound to give value for everything received. Stated concretly, a merchant who fixes a price for his goods is bound to provide the customer with goods which are worth the price, and the customer on the other hand should pay a price sufficient to compensate the merchant for that particular quality of goods. "A special sale" was never held in the Metcalf store for the reason that his goods were always marked at what he considered to be the correct price, and deviation from this price either in favor of the customer or the merchant was, to his way of thinking, inequitable.

Charity in the commonly accepted meaning of the word was abhorrent to Mr. Metcalf's nature. His solution of the charity problem was to provide each person with an opportunity to earn what he needed, but to give it to him without effort on the part of the recipient, was unthinkable. This did not, however, carry him so far as to refuse all charities, for hundreds of dollars were given by him to those who through physical impairment or lack of opportunity were unable to make their own way, but in every case he expected a return whenever a return should become possible. Every appeal was given most earnest consideration, and no cause which he considered worthy was neglected. On the other hand, cheats and shams received scant consideration at his hands. His "No" was not only positive but emphatic.

No hasty opinion was ever given, but a conclusion once reached was

most rigidly followed. At the beginning of the war Mr. Metcalf was greatly disturbed as to the righteousness of the cause of the various belligerents. This rendered it necessary for him to make an exhaustive and comprehensive personal investigation, as the result of which he finally reached the conclusion that the German Empire was wholly wrong and that it would be a world calamity for its arms to succeed. This decision was not a patriotic impulse, but merely a question as to the relative rights and wrongs of the parties. Having reached the conclusion that Germany was wrong he then understood it to be his duty to contribute anything within his power to prevent German success. Consequently, he subscribed not only his quota but far in excess of his quota to every drive or move calculated to bring about German defeat. Furthermore, literally thousands of dollars were given by him voluntariliy and without solicitation, to war activities concerning which no special drive was made, and yet so quietly was this done and with such absence of show, that none but his bankers and intimate friends knew what he was doing. To him it was not a matter of patriotism but one of duty to aid the country which had made his own personal success possible.

Mr. Metcalf's quietness and self repression often caused him to be misunderstood and misjudged by those whose acquaintance with him was merely superfiicial. A blunt refusal on his part to contribute to some call for assistance at times brought the charge of stinginess, whereas if in his judgment the cause had been worthy, the contribution would have been made at once and without comment. The public was unable to understand his refusal of one call for assistance and his compliance with another, to all appearances similar. The answer, however, was simple; the first call was, to Mr. Metcalf's mind, frivolous and unworthy, and the second call was one of merit, but since he never bothered to explain the reasons for his action, he was apt to be considered erratic.

"I Know of No Cause More Worthy"

The belief, so deep rooted in his very nature, that each one should return to society benefits equal in amount to those received by him from society; in other words, the Doctrine of Compensation is in a large measure accountable for the provisions of his will, which are considered by some as eccentric and peculiar. This will was no hasty document written on the spur of the moment, but was the result of years of patient research and intensive investigation. Mr. Metcalf was filled with the profound conviction that the ultimate good of society rests upon the development of a higher class of human beings and that the future welfare of the race as a whole can only be served and improved through the propagation of a superior people. His personal acquaintance with the live-stock business had shown him at first hand the evil results of improper breeding and race selection, and it was a simple matter for him to apply the same rules to human life and conduct. The American Genetic Association to his mind was a pioneer in that field and practically the only organization of consequence engaged in that particular line of endeavor. If there had been another organization with the same ideals and purposes which in Mr. Metcalf's judgment would better serve to carry out these views, the Genetic Association would not have received one penny from him. It was not a matter of sentiment, but it was a case of using what he considered to be the best tools available for his purpose; of returning to society a benefit equivalent to that which he had received from society. A careful perusal of his will discloses this thought running throughout the entire document, yet it is to be noted that he at all times recognized his first duty to his family and provided, as he thought, amply for their needs.

This same philosophy accounts for

what has sometimes been considered as the strange provision for his son. He did not want his son to accept anything which he was not willing and able to return, just as he himself never received or accepted a benefit which he was not willing to return.

These convictions, coupled with a natural reticence of manner and his utter indifference to public opinion caused him to be misunderstood by the public. In many instances he did not take the time or make the effort to explain an action which to him was perfectly clear and logical for the reason that he felt that it would be a waste of words to make the explanation, and waste was not in Mr. Metcalf's vocabulary. He was at times accused of lack of sentiment, yet those most intimately acquainted with him well knew the absolute falsity of such a charge. A more gentle or kinder disposition never existed and his love for his home and family were so deep rooted and profound as to be almost an obsession with him, yet because his heart was not carried on his sleeve and he did not take the trouble to exhibit his emotions to the world he was considered cold and indifferent.

The death of his first wife in 1914 was a terrible blow to him and one from which he never fully recovered. In 1918 he married Miss Helen Martin by whom three children were born. His home life was happy but uneventful and his pride in his three children was wonderful to behold. His death on December 21, 1927, terminated a career of industry and accomplishment. In balancing the books of his life it is to be observed that while he had accumulated a fair portion of worldly goods, his ability and opportunities were such that had his sole ambition been to amass a fortune, he could easily have taken for himself many times that which he did accept, but he retained nothing which, according to the strict dictates of his conscience, he had not earned or did not deserve.

EDITOR'S NOTE:—We have been delayed in publishing this appreciation of Mr. Metcalf because we were not able to obtain from his friends in Wyoming a good photograph of the author of the unique will that was published in the JOURNAL a year ago. We owe a debt of gratitude to his sister, Mrs. Eliza Metcalf Holland, who generously put at our disposal the interesting series of family pictures and scenes in Wyoming which accompany the article.

An Extreme of Human Fecundity

An extreme variation in human fecundity is reported from Italy in the seventeenth century, in an old and illustrious Florentine family. According to Hare's "Florence" (p. 220), a portrait of the lady, which probably is still in existence, bears an inscription referring to a contemporary record. Hare quotes the inscription, which he seems to have copied from the picture. More information may be obtainable from the sources indicated:

> The *Palazzo Frescobaldi* . . . . recalls the memory of Dianora Salviati, wife of Bartolomeo Frescobaldi, who was the mother of fifty-two children, having never produced less than three at a birth.
>
> Dianora Salviati, moglie di Bartolomeo Frescobaldi, fece cinquan'idue figli, e mai meno di tre per parto, come riferisce Giov. Schenchio ne' libri delle sue osservazioni, nuove, ammiraboli e mostruose, cioe nel Libro Quarto del Parto, a carte 144.'
>
> The above inscription is painted on a full-length portrait of the lady in question, in the possession of the Marchesa Leonea Frescobaldi, 1896. Bartolomeo Frescobaldi, born Jan. 18, 1574, died Nov. 5, 1650.
>
> Few families of the XIII century were more illustrious than the Frescobaldi, of whom were Dino, the friend of Dante, to whom the world owes the first seven cantos of the *Inferno*, which he saved and carried secretly to Malespina, when the poet's house was burnt. He was also himself known as a poet, as was his son Matteo in the XIV century.—*Hare, Augustus J. C.*, "Florence," London, George Allen, 156, Charing Cross Road, 1900, P. 220.

MENTAL TRAITS OF IDENTICAL TWINS REARED APART

Case III. Twins "C" and "O"

H. H. NEWMAN

University of Chicago

THIS report deals with the third case in this series and brings out some features that are rather sharply in contrast with those previously reported, as well as some other features that are in general agreement with the findings reported for the other two pairs.

It now appears that each case of identical twins reared apart offers a distinct and peculiar situation that must be studied as a problem in itself. This is especially true of the present case.

All of the cases previously reported, including Muller's case and two of my own, have dealt with female twins. This is the first case of male twins of this sort that has been studied. The Twins "C" and "O" were born in a small Illinois village in 1905. "C" was nursed by the mother for but two months and was then adopted by Mr. and Mrs. C. of Cadillac, Michigan. "O" was kept for five months longer and then put in a Chicago orphanage, from which he was adopted almost immediately by Mrs. Fred O. of Milledgeville, Illinois, a small town, where the family lived for two years after "O's" adoption. A very peculiar circumstance characterizes this case, in that both boys received the given names Paul Harold. When they are together each calls the other "Paul". Since the two foster families knew nothing of each other, it is difficult to account for the identity of names. No doubt, however, there is some good natural reason for this curious coincidence.

The first meeting after separation in early infancy took place on July 4, 1927, just about a year before this study began. Twin "C" happened to discover among some family papers the fact that he had a twin brother who had been placed in a certain Chicago orphanage. He was interested enough to follow up this clue and was led to discover that his twin brother was living in a small Illinois town, Shabbona. Correspondence ensued and a visit was arranged for July 4th. This, I think, was the only meeting until they came to us in Chicago to offer themselves for study a short time ago. The twins behaved almost as strangers to each other and showed little, if any, mutual affection.

Proof of Monozygotic Origin

As in all other cases, proof of monozygotic origin is essential. Physically "C" and "O" are very similar indeed, except in expression and behavior, in which there is a sharp contrast. Though I could not put my finger upon any detail of physical make-up in which there is a well-defined difference, I was impressed the more I saw of them that these young men have entirely different personalities. While "C" and "O" can hardly be classed among the highest grade identical twins that are practically indistinguishable, they are as similar physically as the middle grade of identicals in our collection of fifty pairs of identical twins reared together. There could be no question in the mind of the experienced student of twins that they belong to the monozygotic category, for they are decidedly more similar than any pair of dizygotic twins in our collection.

Table I on the next page gives their physical characters in convenient form.

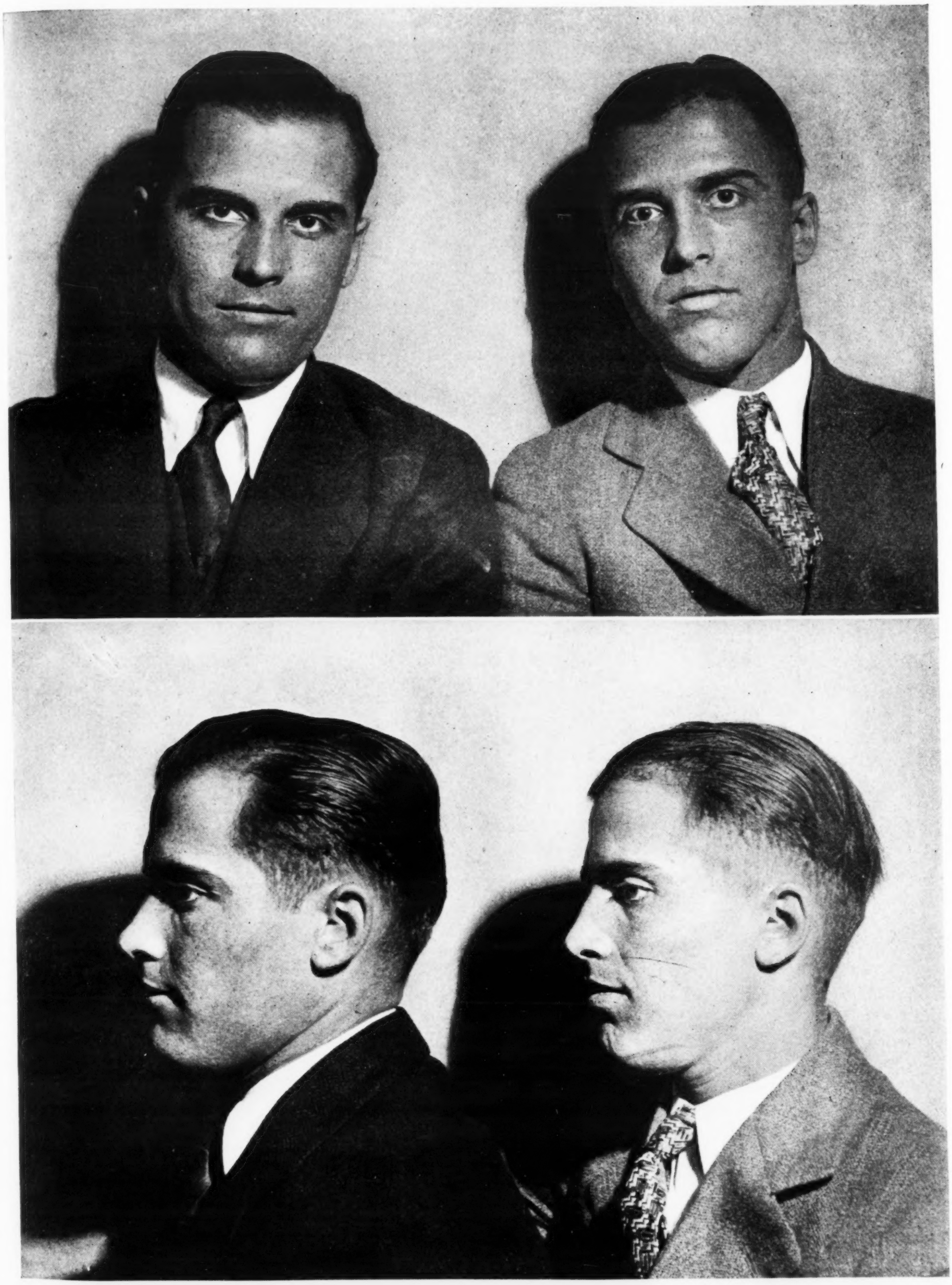
The measureable features of these

twins are remarkably similar except that "C" is in better physical condition, as is reflected in his ten pounds greater weight, which is well distributed at all body levels. The greater amount of flesh is shown in all measurements except in the hips, where "O" is a trifle larger. "C" is in nearly every respect, height, head size and in many other parts, a shade the larger of the twins. Although both twins claim to be purely right-handed, "O" shows by tapping tests, especially in wrist tapping, that he is probably a native left-hander. That "O" is a native left-hander, trained to be right-handed, is borne out by the fact that his left biceps and left ankle are both larger than the right. The fact that he has also the smaller head and is the less vital and forceful of the pair accords with the general rule for identical twins, that the twin derived from the inferior side of the embryo has the smaller head and usually shows signs of asymmetry reversal.

In body build, posture, walk and general behavior, the twins are strikingly

TABLE I—Physical Peculiarities of "C" and "O"

	"C"	"O"
Height standing	62.8	62.4
Height sitting	33.5	33.4
Weight	124 pounds	113¾ pounds
Head length	18.6 c m	18.4 c m
Head width	15.3 c m	14.8 c m
Hair color etc.	Medium brown, soft in texture, thinning in front. Clockwise crown whorl.	Same in all respects
Eye color.	Red-brown, self-colored	Same
Skin texture and color	Medium fair and clear, medium heavy dark beard.	Same
Features.	Brows a little more promirent; Lower face a little fuller, due to being fleshier in whole body; Expression more determined.	Chin a little more prominent. Lips a little fuller; Weaker less determined expression.
Ears.	Normal in shape and position	Strikingly similar
Dentition	Teeth small and regular. Three lower molars filled.	Remarkably similar, Two lower molars filled
Shoe size	5½	5½
Glove size	7½	7½
Chest measure	33¾" normal; 35¾" expanded	32" normal 34½" expanded
Hips	33½ inches	33¾ inches
Thighs	R-21 in. L-20¾ in.	R-20⅛ in. L-19 in.
Ankles	R-8¾ in. L-8⅝ in.	R- 8½ in. L-8¾ in.
Biceps	R-11 in. L-11 in.	R-10⅜ in. L-10¾ in.
Arm stretch	62⅛ inches.	62¼ inches.
Finger height from floor	22.6 inches.	22.5 inches
Hat size	7⅛	7
Tapping tests-----		
Wrist	R-81 L-74	R-88 L-98
Finger	R-78 L-74	R-88 L-83



"C" "O"

CITY-BOY AND COUNTRY-BOY

Figure 7

Separated shortly after birth, "C" spent his life largely in cities, while "O's" environment has been distinctly rural. In intelligence tests the twins differ but lit'le, but the impression of observers and some of the tests emphasize a marked difference in their personality.

"O" **HANDPRINTS OF THE TWINS** "C"

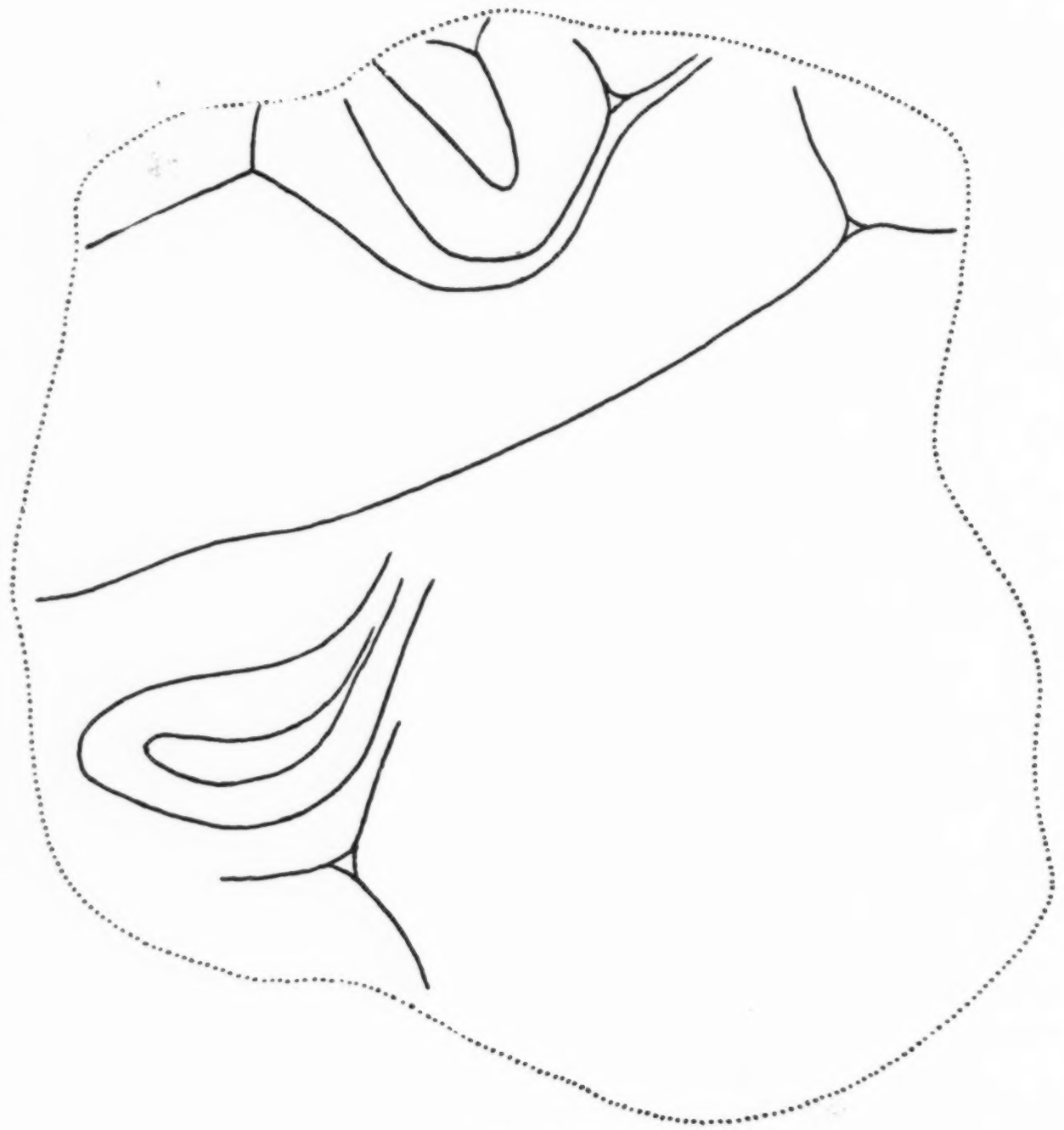
Figures 8 and 9

"O's" left hand, on the left, is to be compared with "C's" left directly below it (Figure 9). In the hand and fingerprint similarities we have almost certain evidence of identity. The left hands are rather more similar than the rights, and there is much closer cross resemblance between the two lefts and the two rights than there is between the two hands of either twin. The principal patterns in the palm prints are outlined in Figures 10 and 11. (In preparing these handprints for reproduction the right hands were inadvertantly exchanged, so that "C's" *right* hand appears opposite "O's" left. The risk of injuring the prints was so great that it was deemed unwise to correct the error.)

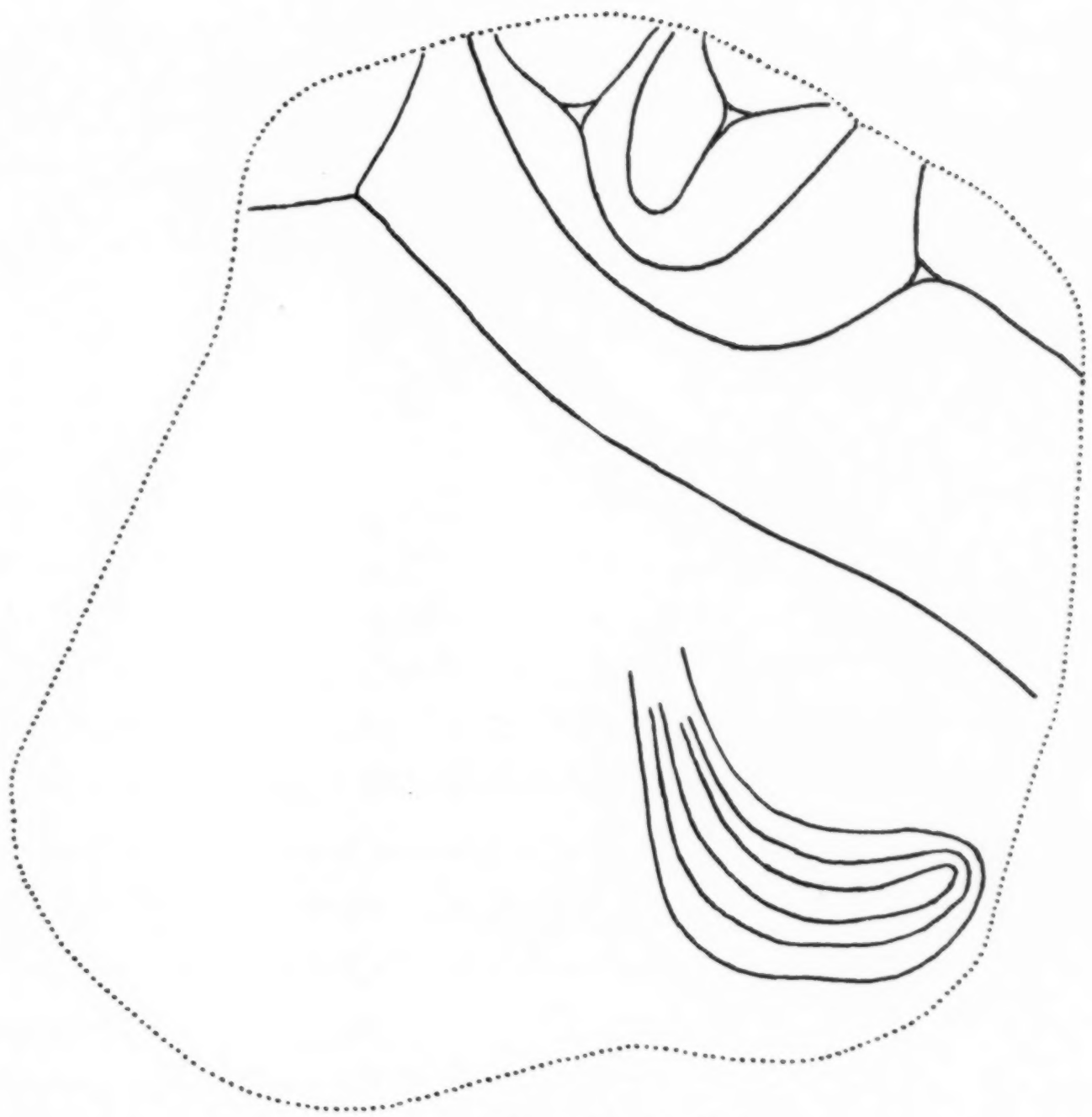
between the two lefts and the two rights than there is between the two hands of either twin. The principal patterns in the palmar prints are outlined in Figures 10 and 11. (In preparing these handprints for reproduction the right hands were inadvertantly exchanged, so that "C's" right hand appears opposite "O's" left. The risk of injuring the prints was so great that it was deemed unwise to correct the error.)

"C"

"O"



Left Hand "O"

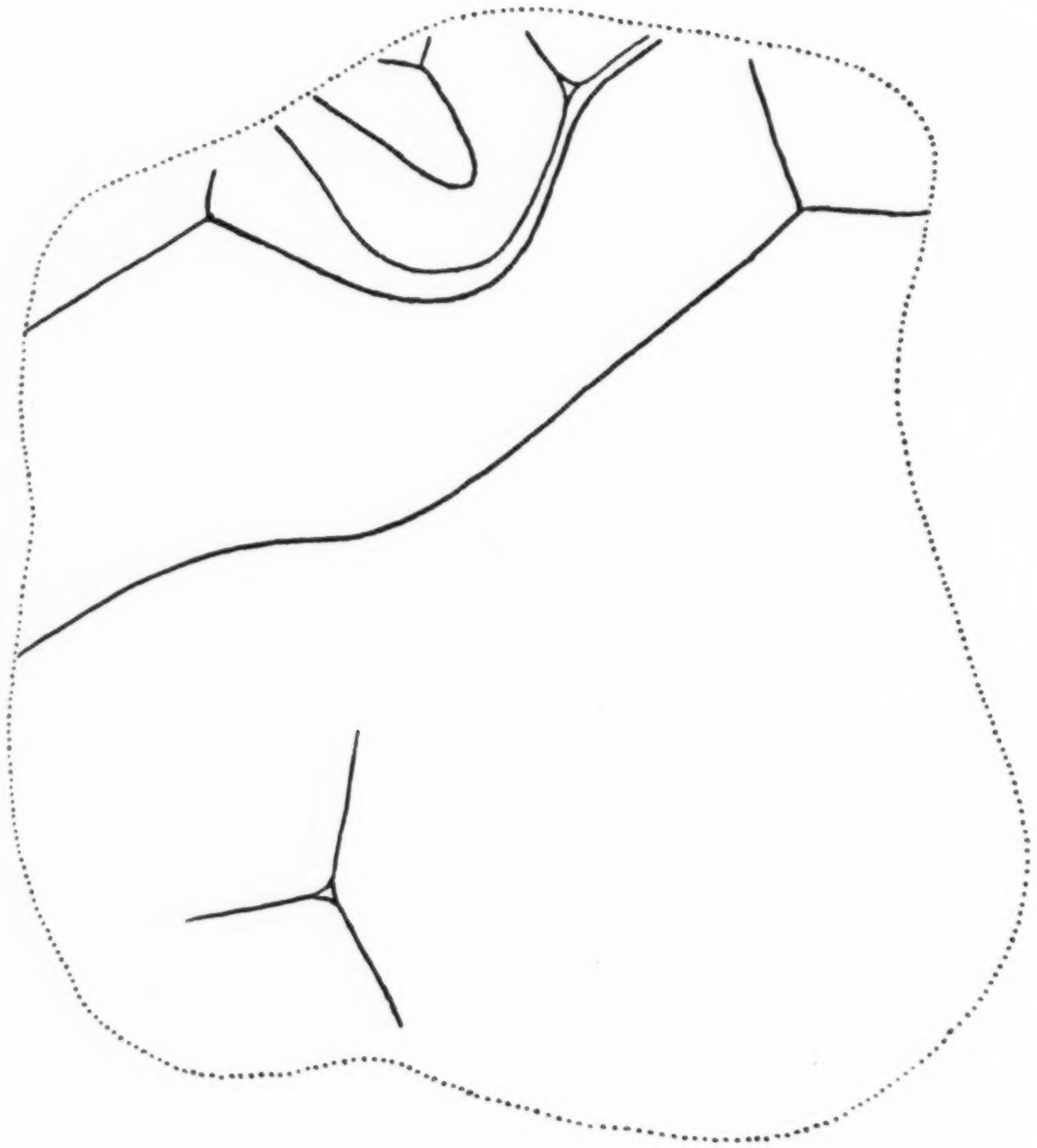


Right Hand "O"

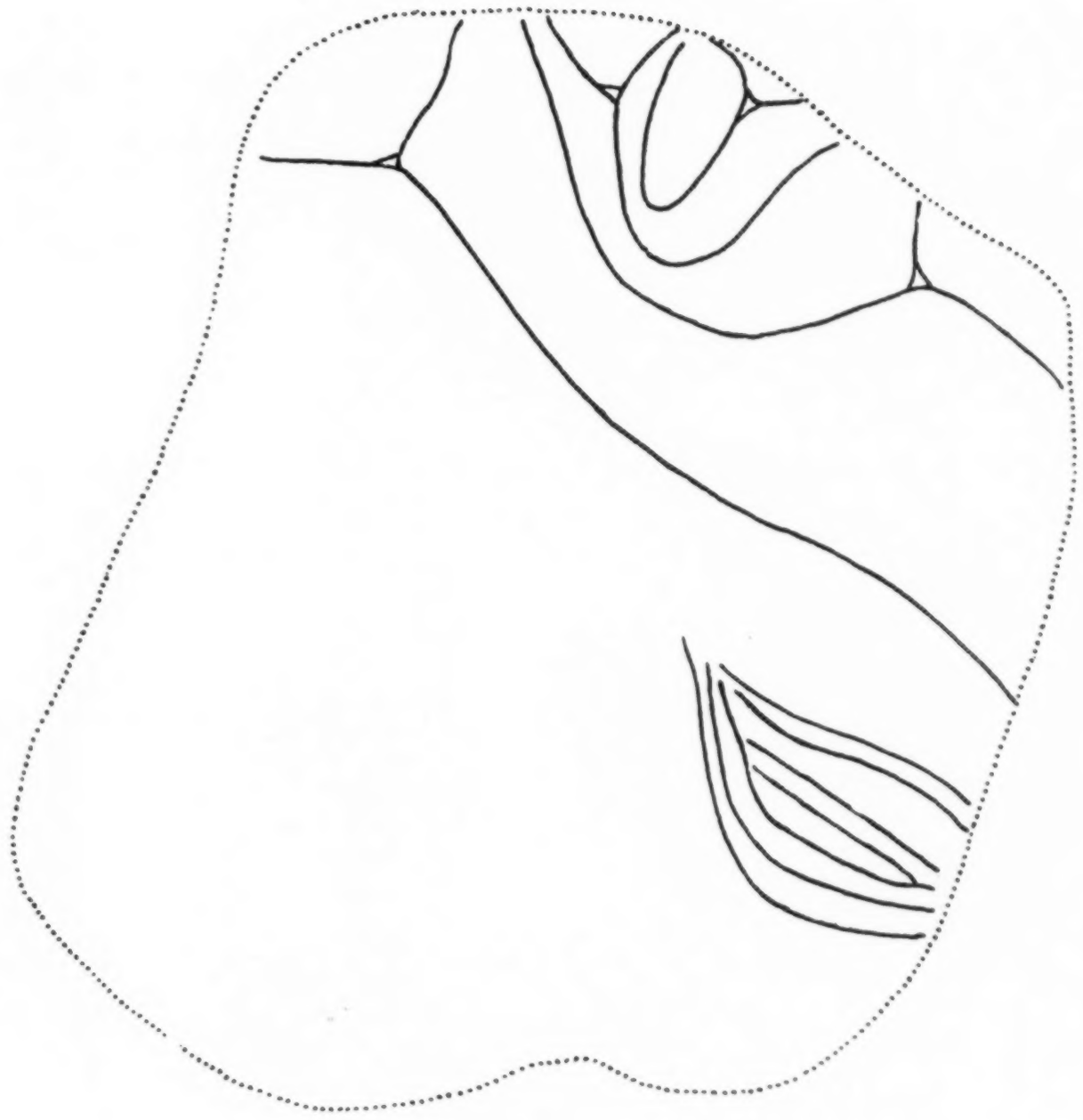
PALM PATTERNS

Figures 10 and 11

The resemblance of right with right and left with left is typical of the cross resemblance found in identical twins . It is evidence of earlier separation of the embryonic primordia than in the cases in which mirror-image resemblance is found.



Left Hand C



Right Hand C

FINGERPRINT SIMILARITIES

Figure 12

Enlarged prints of left ring finger of the twins, C's at left, O's at right. These prints bring out the amazing similarities in the patterns, not as marked as this in all figures, but sufficient to leave little doubt that the twins developed from a single egg.

similar. Both are long in the trunk and short in the legs, both have peculiarly shaped hands with the thumbs set unusually low on the palm, both are unusually short in stature, and both have relatively large, well-shaped heads. The eyes and mouth have a different expression in the two youths, but this is due not to their morphology, but to the different ways in which the muscles of expression have operated in the two individuals. Most of the differences are clearly sensed, but are of an intangible, subjective sort and difficult to describe.

Finger and Palm Print Evidence

The pattern formula for the fingers is as follows:

	Right hands					Left hands				
	1	2	3	4	5	1	2	3	4	5
"C"	U,	U,	U.	W^{u},	U,	U,	R,	U,	W^{u},	W^{u},
	1	2	3	4	5	1	2	3	4	5
"O"	U,	R,	W^{du},	W^{u},	W^{du},	U,	R,	R^{d},	W^{u},	W^{u},

Here the two left hands are in practically all their peculiarities much more nearly similar than they are to the respective right hands. This resemblance is stronger than the formula indicates, as digits 3, 4, and 5 of the two left hands are peculiar in pattern and remarkably similar in detail. (See Figures 8, 9 and 12). The quantitative values of the finger patterns, the total of the five fingers of each hand being used, are as follows:

"C"	Right—49	Left—53	Total—102
"O"	Right—57	Left—48	Total—105

The patterns are very complex and extensive. Hence it is difficult to count all the ridges accurately on account of the fact that in both twins several of the patterns are double-twisted loops that extend far up the side of the finger. Even though the fingers were well rolled in the printing process, it did not seem possible to include the whole pattern in clear condition. The method of giving values to groups of ridge counts helps to remove any large error in the quantitative values. It will be noted that all values on both twins are exceptionally high, a decidedly strong resemblance in itself, and one seldom duplicated in our one hundred pairs of twins.

The additional circumstances that the values of the right hand of "C" and the left hand of "O" are very nearly equal, and the total values of both hands show only three points difference, are both thoroughly in accord with a monozygotic diagnosis, especially since "O" is diagnosed as a left-hander on several other counts.

Palm print evidence. The palm main line formulae and patterns are as follows, using the notation now standardized by Cummings and his colleagues:

	Right hands	Left hands
"C"	11,9,7,5 O,A,O,O,O	11,7,7,5 O,A,O,O,O
"O"	11,9,7,5 O, a, O,O,O	11,7,7,5 O,O,O,O,O

These patterns are shown in Figures 10 and 11, which indicate most emphatically the striking resemblances between the palms of these twins. Here we get the typical form of cross resemblance so characteristic of identical twins, in which the two right hands have the same formula and the two lefts the same, but rights differ from lefts. The fact that "C" has a moderately well-developed hypothenar loop of the "A" type in both hands and "O" has the same pattern in a reduced form on the right hand and no pattern at all on the left hand is consonant with the incidence of such patterns among identical twins in general. The palm print evidence of monozygotic origin of these twins is of itself conclusive.

General diagnosis. When all the criteria of diagnosis are applied to "C" and "O", they must without question be classed as identical twins. Had they belonged to our carefully diagnosed collection of one hundred pairs of same-sexed twins, they would have been placed among the middle grade of identicals in which reversals of asymmetry of various sorts are common.

Enlarged prints of left ring finger of the twins, C's at left, O's at right. These prints bring out the similarity as this in all figures, but sufficient to leave little doubt that the twins developed from a single egg.

Histories of the Twins

History of "C". "C" lived with his foster parents in the small Illinois town where he was born, until thirteen years of age, attending school there. At thirteen years, when in the eighth grade, he moved to Lake City, Michigan, where he lived two years and began high school. During the middle of his first year in high school he moved to Cadillac, Michigan, entered high school and graduated in 1923 when eighteen years old. After graduation he worked for two years in a furniture factory, doing office work. In 1925 he left Cadillac and took a ten months' course at Ferris Institute, a commercial and technical school at Big Rapids, Michigan. Then for about eighteen months he did office and sales work in a Grand Rapids factory. At the time of the examination "C" had been studying accounting for three months at a good business college in South Bend. Altogether "C" has had a grade school, a high school and a fairly extensive business school training, much of it in larger towns and cities, especially during late years.

"C's" foster parents were people in moderate circumstances with no children of their own. The foster father is a painter and paper hanger with good wages, and has had only a common school education. The foster mother had about the same amount of education. In the home there were few, if any, books or better-class periodicals. "C" was brought up as a typical only child and had his own way to a considerable extent.

As a baby "C" was rather sickly. He did not walk until two years old. He had the measles at twelve years and chicken pox at ten.

History of "O": The foster parents of "O" moved about a great deal from one small Illinois town to another. They have never lived in cities. The environment of "O" has been distinctly rural from birth. "O" attended grade school in three different villages or country schools. He took his entire high-school course in Shabbona, Illinois, where he graduated in 1923, at the same time that his brother was graduating in Cadillac, Michigan. The year after graduation "O" spent in traveling in the Western States and in attending Iowa State College, where he studied architectural engineering for two quarters. Before the year was over he discontinued his college work ostensibly because of difficulties with mathematics. Since leaving college "O" has been assistant postmaster at Shabbona, Ill.

The foster parents of "O" were somewhat more educated than those of "C". The foster father is a telegraph operator, reads a good deal, and has had a year in business college. The foster mother was separated from her husband about ten years ago, and a housekeeper has since then managed the family. She seems to have done well by them and to have exerted a good influence. "O" was brought up with a foster-brother and foster-sister aged now, respectively, fourteen and seventeen years. All three children were treated alike and were not given undue liberty. The home condition is described as comfortable, but not luxurious. "O" had scarlet fever and mumps almost simultaneously at the age of eleven, measles at eight or nine, a light case of smallpox at fifteen. He had tonsils and adenoids removed at sixteen years.

Histories compared. There is not much contrast either in educational careers or in home environments in the two twins. "C" has had about a year more of formal education than "O" and possibly in larger and more efficient schools for the most part. "C" was an only child, "O" one of three. "C" has lived much more in cities of memium size; "O" has seen little of city life and appears much less sophisticated. *The whole environmental complex of these twins is in general similar rather than different.* This circumstance does not detract seriously from

their value as objects of study, especially as they may be used as a check on those cases in which the environment of the twins shows stronger contrasts.

Let us now proceed with an account of the results of tests for mental and emotional resemblances and differences.

Mental Tests

1. *Stanford-Binet Mental Test.* The results of this test may best be given in a tabular summary:

	"C"	"O"
Mental age	15 years, 11 mos.	16 years, 2 mos.
I. Q.	99	101
Vocabulary	12,060 words	10,260 words

The difference in mental age, as determined by this test, is only three months, which is much less than that of the average fifty pairs of identical twins reared together (8.4 months). The difference in I. Q. is only two points and, naturally, is also much less than that of the average of twins reared together (5.3 points). It may be concluded that these twins reared apart are not significantly different mentally, though separated for over twenty years. What little difference is present is in favor of "O" who has had a little less formal education.

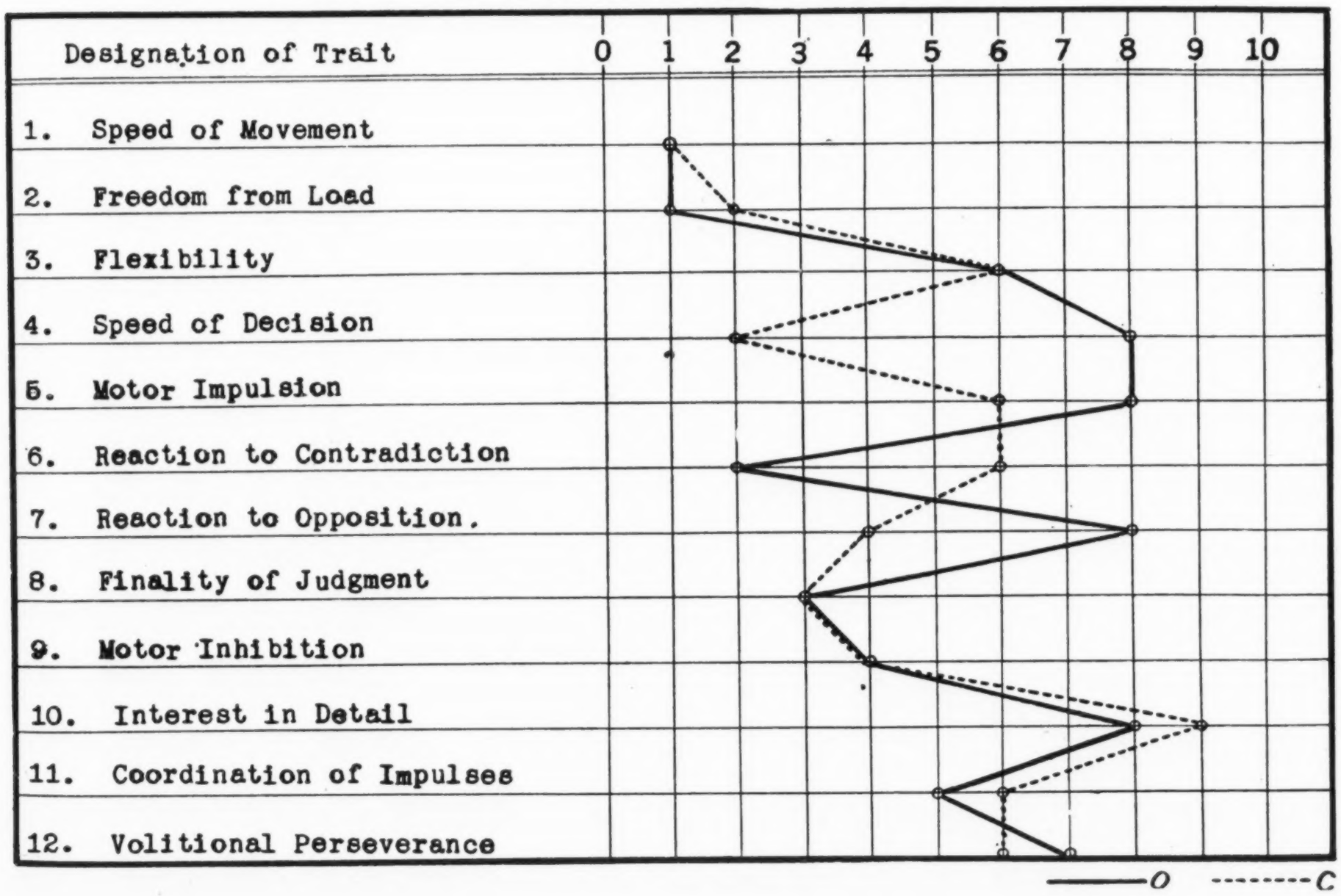
2. *Thurstone Psychological Examination.* This test is a good deal more severe and involves more of the results of training. The following scores will show the differences between "C" and "O".

	"C"	"O"
Completion	16	18
Artificial language	23	17
Analogies	26	20
Arithmetic	12	14
Opposites	24	15
Total	101	84

The percentile rank. as based on the scores of 5,077 college students, is .35 for "C" and .17 for "O", a difference of .18 in ranking. This means that "C" is in the third quartile and "O" in the fourth. Both boys made highest ranking in "opposites" and lowest in "arithmetic".

Here "C" shows considerably greater mental ability than "O", in contrast

TABLE II—Will-Temperament Profile of Twins "C" and "O"



with the results of the Stanford-Binet test, where "O" was a little more proficient.

3. *International Group Intelligence Test (non-verbal)*:

	"C"	"O"
1. Counting cubes and matching	11	11
2. Associations (pictures)	34	30
3. Similarities (pictures)	33	28
4. Similarities (facial expressions)	17	20
5. Mazes	11	12
6. Rhythm	12	9
7. Pictorial analogies	31	28
8. Narrative completion	7	8
Total	156	146

The slight difference shown here again favors "C", but is not considered as very significant. The resemblances are more striking than the differences.

4. *Otis Self-administering Mental Test.* In this test "C" attempted 54 items and got 40 right, giving an I. Q. of 110; "O" attempted 48 items and got 32 right, giving an I. Q. of 100. Here "C" is distinctly superior to "O", for the average differences in I. Q. in this test for fifty pairs of twins reared together is 4.5 points.

1. *Stanford Achievement Test.* Subject age in years and months.

	"C"	"O"
Sentence meaning	19-4	15-10
Word meaning	16-11	16-8
Arithmetic (computation)	14-1	15-7
Nature study and science	17-6	16-1
History and literature	15-9	15-4
Language usage	18-6	15-4
Spelling	17-6	16-2

"C" is superior in all tests except "arithmetic". "C's" educational age is seventeen years one month; "O's" is fifteen years nine months, a difference of sixteen months. This is 2.5+ times as great as the average of fifty pairs of identical twins reared together. "C", the slightly more extensively educated twin, is distinctly superior.

Emotion and Temperament Tests

6. *Woodward - Mathews Questionnaire of Emotional Stability:* "C" gave thirteen unfavorable replies, "O" gave fifteen unfavorable replies. The two boys gave fifty-three similar responses out of seventy-five questions. The differences between them are that "O" gets cross easily and his feelings are easily hurt, "C" seems much less sensitive. "O" feels that he is not treated right by his family, "C" has no such feeling. "O" has much more difficulty in making up his mind than "C". "C" lives a make-believe life and "O" does not.

In this test the resemblance in general is very great, but some of the contrasts are very striking and important in that they seem to give a key to the very different personalities of the boys.

7. *Kent-Rosanoff Association Test:*

	1000 normal subjects	"C"	"O"
Common reactions	91.7%	98	100
Individual reactions	6.8	1	0
Doubtful reactions	1.5	1	0

Both boys gave more common reactions than the "normal" group upon which the list was standardized. The value of "C's" reactions averaged 163, that of "O's" averaged 133, meaning that on the average "O's" association was given by 163 of the 1000 persons, and "C's" by 133. Out of 100 associations made, only 29 were the same for the two twins.

"C's" reactions are on the whole tangibly more "normal" than "O's", a fact brought out more strongly by subsequent tests and in agreement with the writer's personal impression derived by observation of them for some hours.

8. *Downey Will-Temperament Test:* The will-temperament profile (Table II) shows the resemblances and differences graphically. The tests indicate on the whole fundamental similarities. Both are low in "Speed of Movement" and "Freedom from Load". Both are quite high in "Interest in Detail". In eight out of twelve tests there are less than two points difference between them. The greatest difference is in "Speed of Decision" where "C" is 6 points superior to "O". On the whole, "O" ranks a little higher, 61 as compared with 55 for "C", showing that neither has a very forceful personality. Neither is mobile or rapid-fire, but "O" is a

little higher, 24 as compared with 17 for "C". Both are average in control, care, deliberation, force and aggressiveness. This test on the whole emphasizes the fundamental temperamental similarity of these twins, at least insofar as temperament is measureable by this test.

9. *Pressy X-O Test of Emotional Reaction.* The table below* indicates the number of words crossed out.

The results of this test express more objectively than any others given what one feels when in association with the twins. "O" is unquestionably the more temperamental and emotional. The difference is obvious from the first acquaintance. The figures show that "O" has very much greater "affectivity" than "C", for "O" comes very close to the 75th percentile (Q_3) and "C" is decidedly below the 25th percentile (Q_1). More than half of all the individuals in the group used for standards would fall between them in degree of "affectivity". One gets the impression in associating with these twins that "C" is phlegmatic and blasé, while "O" is excitable and näive.

In "unpleasant words" the contrast is greatest, "C" being very slightly above the 25th percentile, while "O" is considerably above the 75th percentile. Essentially the same difference is seen in connection with things "thought wrong" and in "worries".

Analysis of the details of the tests reveals a few more significant differences. "O" is most affected by "self-feeling" words, "C" least affected by that type. The "worries" test is quite significant and is given herewith in more detail:

Type of personality indicated	"C"	"O"
Suspicious (paranoid)	4	4
Jumpy (neurotic)	5	13
Self-conscious (shut-in)	7	10
Melancholic	6	16
Hyperchondriacal	7	12
Total	29	55

"O" is decidedly more neurotic and melancholic than "C". This conclusion is strongly borne out by detailed study of the peculiarities of "O's" associations.

Summary and Conclusion

This case emphasizes more sharply than any of those previously reported that it is quite impossible to generalize about the effects of environment and training upon the hereditary make-up of twins reared apart. In this case the environment and training of the twins were closely similar in general, at least insofar as we were able to ascertain the facts. Yet the "personalities" of the boys are utterly different. So opposite is the impression made by them upon all the observers that we were forcibly struck by it from the beginning. Yet the only test that adequately expresses this obvious difference is the Pressy X-O test.

In native mental ability they seem to be nearly identical. In educational achievement "C", the boy educated in larger towns and who is still studying, ranks definitely higher than "O", as might be expected. In spite of this, it must be concluded that mentally the two boys are practically equal. The one outstanding difference is in their general personalities. "C" impresses one as more dignified, more reserved, more self-contained, more unafraid, more experienced, and less friendly. He seldom smiles, has a more serious expres-

*Pressy X-O Test.

	"C"	"O"	Group of 114 college students Q_1	Md.	Q_3
Test I (unpleasant words)	34	80	27	41	52
Test II (words associated in mind with given word)	34	38	41	55	70
Test III (things thought wrong)	64	84	60	73	86
Test IV (worries)	29	55	33	46	55
Total	161	257	200	230	260

sion about the brows, eyes and mouth. He stands more erectly with chin held in and brows drawn down somewhat over his eyes. "O" is the opposite in all of these respects. He is more the typical country boy, laughs readily and is not on his dignity at all. He seems to seek society more than "C" and enjoys having a good laugh. Because of the difference in expression, "C" gives the impression of having a stronger nature and is distinctly good-looking, while "O" seems to lack something in this respect. The feminine observers of these twins feel more strongly attracted by "C" than by "O". This may afford a clue to some unrecorded environmental agencies that have had to do with moulding these two very different personalities.

Books Received

BOOKS are acknowledged in this column as received, and such acknowledgment must be regarded as sufficient return for the courtesy of the sender. As far as space permits, books that contain material of special interest to the readers of the JOURNAL *will be reviewed in later numbers.*

INTERNATIONAL DIRECTORY OF PEDIGREE STOCK BREEDERS: An Index of Pedigree Stock Breeders in Great Britain, the Overseas British Dominions, and all Civilized Countries, a Handbook Recording Breeds and Stock Breeding, etc., in Every Country of the World." Maps and numerous illustrations. Compiled and edited *by* R. DE TOLL. Pp. 821. Price $6.00. Published by The Vernon Press, Ltd., 23 Fleet Street, London, E.C.4, England, 1928-1929.

MEMORIALS DO INSTITUTO OSWALDO CRUZ. Vol. XXI, No. II, pp. 193, 4 parts. Rio de Janeiro-Manguinhos, 1928.

Containing a monograph on the Flacourtiaceae, whose seeds contain an oil analogous to that obtained from Chaulmoogra seeds.

POSTERITY, in the Light of Science, Philanthropy, and Population: "Is postery to be sacrificed for want of a sane outlook upon population? Custom, prejudice, ignorance, and greed are the fetters; science, ethics, enlightenment, and co-operation are the deliverers Which will prevail?" This question is discussed by the author, with a foreword by Major Leonard Darwin. *By* FRANK W. WHITE, L.E.C.P. & S.E. Pp. 139. 10 Chapters. London, Watts & Co., 1929.

LIVE STOCK BREEDING IN NORWAY: *By* J. BAASHUUS-JESSEN. Pp. 27. 9 Illustrations. Oslo, Norway, Rambaels Trykkeri, 1929.

EMOTION AS THE BASIS OF CIVILIZATION: *by* J. H. DENISON, with an introduction by Prof. George Foot Moore. Pp. 555. 29 Chapters, 3 parts. Price $5.00. New York, Charles Scribner's Sons, 1928.

PROCCEDINGS OF THE THIRD PAN-PACIFIC SCIENCE CONGRESS, TOKYO, 1926. Edited by The National Research Council of Japan. Vol I, 1220 pages, 2 parts, 8 chapters. Vol. II, 1458 pages, 11 chapters. Tokyo, National Research Council of Japan, 1928.

PHYSIOLOGY OF BONE, Normal and Pathological: It's Problems: *By* R. LERICH and A. POLICARD—Authorized English Translation by Sherwood Moore, M. D., and J. Albert Key, M. D. Pp. 236. 11 Chapters. 33 Illustrations. Price $5.00. St. Louis, The C. V. Mosby Co., 1928.

ZUCHTUNGSLEHRE: Eine Einfuhrung fur Zuchter und Studierende. *By* DR. C. KRONACHER. Pp. 365. Price 15 Marks. Berlin SW 11, Paul Parey, 1929.

A compendium for breeders and students, by a German authority.

"Heritable Character" Paper Wrongly Numbered

In the December (1928) *Journal,* Hayes and Brewbaker's paper on Sorghum-Tassel Maize was numbered XXXIII in the Heritable Characters Series. This is an error as the paper is really XXXII in the series. The next paper to appear in the series will bear the correct number XXXIII.

A "HALF AND HALF" SKIN-COLOR MOSAIC IN THE CHICKEN*

W. V. LAMBERT

Iowa State College

ONE of the most substantial properties of the living organism is its stability. It is endowed with certain potentialities at the time of fertilization, and it retains these with a remarkable constancy through all the myriads of cell divisions during development, and during the course of its life. Occasionally, however, changes other than normal occur in the cells of the developing embryo and such changes may be reflected in the adult by an unusual mosaic of color or pattern.

The mosaic shown in Figure 13 was called to the writer's attention by Mr. H. A. Bittenbender of Ames, Iowa. It consisted of a mature hen, one half of whose body was white-skinned and the other half yellow-skinned. The division line of the color extended the entire length of the body along the median line. Unfortunately the bird had been killed, and picked at a poultry packing plant, so no history of it was available. It resembled a Leghorn although the size was a little larger than that of the average Leghorn.

The most plausible explanation of the origin of such a mosaic is somatic non-disjunction of the chromosomes carrying the genes for skin color. This will be apparent after an explanation of the genetic relations of white and yellow skin color. White skin is a simple dominant over yellow skin, the inheritance of these colors being dependent upon the action of one pair of genes. White-skinned birds may normally, therefore, be of two types, homozygous (*WW*) or heterozygous (*Ww*), while yellow-skinned birds must always be normally of one genotype (*ww*).

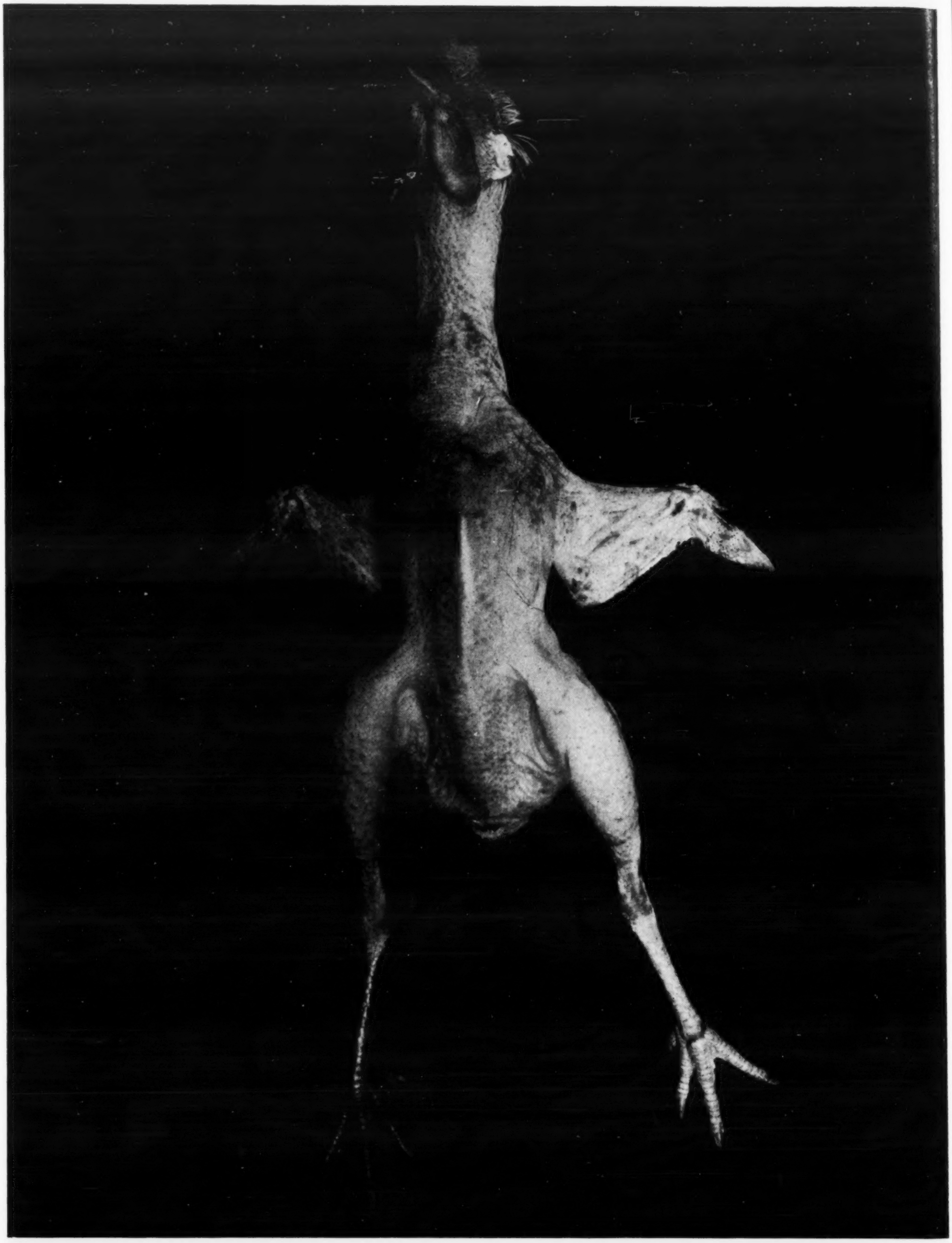
To have become such a mosaic by the process of non-disjunction the chicken shown in Figure 13 must have been heterozygous for white skin, namely of the genotype *Ww;* and the non-disjunction must have occurred at a very early stage of cell division, possibly at the first cleavage. If the bird were heterozygous (*Ww*) and the chromosome carrying the white factor failed to divide normally at the first cleavage, then one daughter cell would have contained two factors for white and one for yellow. The other daughter cell would have contained only one factor, and that for yellow. According to this hypothesis, the white-skinned part of the bird should have been of the composition (*WWw*) and the yellow-skinned half of the bird (*w*).

The mosaic might also be explained by a gene mutation immediately following the first cell division. If the zygote had been homozygous for yellow skin (*ww*) a dominant mutation in one of the pair of genes would have resulted in a half yellow and half white-skinned bird. This possibly may have been the condition, for the chicken resembled a Leghorn, a breed in which the skin color is normally yellow.

If the zygote had been heterozygous for skin color (*Ww*) and a recessive mutation had occurred in the *W* gene following the first cell division, the same result might have been obtained.

Somatic non-disjunction is the most plausible explanation. Non-disjunction has been observed many times in Drosophila, and in those cases in which the flies were hybrid for certain characters mosaics of pattern have resulted.

*Paper 29, Genetics Department, Iowa State College, Ames, Iowa.



HALF YELLOW AND HALF WHITE

Figure 13

One half of the body of this chicken had a yellow skin and the other half a white skin. This photograph was made with a pan-chromatic film in order to bring out the difference in color, but unfortunately the difference is shown clearly only in the shanks and feet. The line of color division extended over the entire body at the median line.

A similar misbehavior of the sex-chromosomes has been found to be responsible for the intersexual types or gynandromorphs in this species. While such abnormal division of the chromosomes has not been reported frequently in the higher animals there is no *a priori* reason why it should not occur. It is probable that, when the genetic analysis of these species is more complete, more and more mosaics similar to the one here reported will be observed. When they do occur their breeding behavior should be checked. In the chicken, if the mosaic were a female and of the type here reported, this would be relatively simple. Only the left ovary develops and, therefore, only the type of egg characteristic of the genotype of the left half of the bird would be produced, providing, of course, that the non-disjunction had occurred early enough to have been included in the germinal tissue.

Heredity and Environment in Cancer

* * *There are strong grounds for thinking that this [soot, tar, shale oils, and other products of destructive distillation] is the environmental factor which connects a high cancer incidence with civilization and town life. Man is an artificial animal, and he is evidently far from perfectly adapted to the surroundings which he makes for himself. Human and animal experience also agree in showing that cancer follows injury only after a long latent period, during which the irritation may or may not be continued. The interval in mice is of the order of one-third of their natural span of life: a corresponding period of 15 to 20 years is suggested by the human data. If man lived, like a wild animal, only for the years of his physical perfection and generally finished about 30 to 35, few people would have malignant tumors. They are not common until ages of 40 and upwards are reached—a prime fact in their epidemiology which is consistent with the view that irritants are the most important stimuli of cancerous growth, especially when this mode of response is given better chances to emerge by man's unnatural habit of keeping himself alive a good deal longer than was intended.

Whether irritants produce cancer or not depends also on the tissues which are involved. Recent observations show in a variety of ways that the constitution of the irritated individual is far from immaterial. Experimentally, it is easy enough to make malignant tumors with tar in mice, difficult or next to impossible in rabbits, rats, or guinea pigs. Within the same species, races and individuals differ in the same way. Mice are so prone to develop "spontaneous" cancers that the incidence of the disease may be observed in them as it may be in man. Some strains are more cancerous than others, and the original demonstration by the Imperial Cancer Research Fund that a tendency to have cancer could be exaggerated by selective breeding, has been very fully confirmed by the massive observations of Miss Slye, Prof. Leo Loeb, and others. Races have been obtained in which nearly every mouse dies of cancer; other races in which cancer is almost unknown; and it is quite clear that the liability to respond to irritation by producing a cancer is a heritable constitutional quality, depending apparently on more than one mendelian factor, and difficult to trace through man's promiscuous breeding.

We have also learned in recent years that these constitutional differences may be acquired as well as inborn. * * * The development of one cancer thus produces some alteration in the whole economy of the animal, which makes it everywhere less responsive to carcinogenic irritation. — Editorial *Nature* (London) January 5.

A NATURAL WHEAT-RYE HYBRID

Figure 14

At left—Fultz wheat, the seed parent; *Center*—Hybrid; *Right*—Rosen Rye No. 3, the pollen parent. The hybrid was extremely late in maturing, but was intermediate in most characters.

WHEAT-RYE HYBRIDS

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NATURAL wheat-rye hybrids have been reported from time to time in agronomic literature. The occurrence of such plants in nature is believed to be a matter of sufficient interest to justify their description.

The wheat-rye hybrid plants were found while rogueing an increase plot of Fultz 7 wheat grown on the Agronomy Farmy at Morgantown, W. Va., during the summer of 1928. During the 1927 season Fultz 7 had a considerable mixture of volunteer rye. The wheat was carefully rogued before harvest, but there was ample opportunity for crossing to occur since the blooming dates for wheat and rye coincide to a greater or less extent.

The hybrid plants resemble wheat rather closely, although they were intermediate in most plant characters. The hybrid plants were completely sterile and were still green when the Fultz 7 parent was fully ripe. They were somewhat taller than the surrounding wheat plants although not quite as tall as the rye parent as can be seen from the accompanying photograph. The heads of the hybrid plants were somewhat longer than wheat and show a few apical awns. The seed parent, Fultz 7, is awnless. The peduncle is similar to rye in that it is pubescent and tends to be pithy for an inch or more below the head. The shape and size of the glumes are similar to wheat although the lemma has a prominent ciliate keel as in the rye parent.

Approved as Scientific Paper No. 63, by the Director of the W. Va. Agr. Exp. Station,

CORRESPONDENCE

Heredity in Adherent Tongue

DURING a recent visit to Minnesota, my father, who is professor of orthodontia in the Dental College of the University, told me of an interesting case of the inheritance of a speech defect that had come to his attention. The following is a statement of the case:

Patient, male; age, 19; locomotive fireman, has decidedly defective speech, very difficult to understand him. His speech is like that of a person having congenital cleft palate of pronounced type.

In general, the mouth appeared to be quite normal. The upper dental arch is a little narrower than normal in the anterior portion and slightly retruded so that the incisors meet end to end. The palate or vault is slightly higher than normal. None of these departures from normal, however, have anything to do with the defective speech. There are thousands of mouths with even greater variation from normal as regards the dental arches, occlusion of the teeth, and the palate in which there is not the slightest defect in speech.

Upon examination it was found that the patient could not elevate the tongue to make contact with the palate, particularly in the posterior region, as occurs in producing the sounds of k, q, hard c and hard g.

The patient could protrude his tongue quite freely, but in trying to elevate it it seemed to be drawn into the throat and would elevate only slightly.

The family history showed that the father had defective speech noticeable particularly when talking rapidly. He also had an uncle with defective speech.

The father was one of a family of eight children, *four boys* and *four girls*. One of the brothers had faulty speech about the same as the father, the other two brothers had very defective speech. The *girls* in this family had *normal* speech.

The patient here mentioned was one of eight children, *four boys* and *four girls*. *All of the boys have defective speech, while the speech of the girls is normal.* The children are in the following order with ages shown: girl, 26; boy, 25; girl, 22; girl, 21; boy, 19 (patient); boy, 13; girl, 11; boy, 7.

The speech of the first boy is faulty about the same as that of the father. The second boy (the patient) has decidedly defective speech. The third boy's speech is defective about the same as that of the father. The fourth boy's speech is only slightly defective. The patient thinks his speech is more defective than formerly. Was unable to learn whether the speech of the other boys had undergone any change for better or worse since childhood. The four boys resemble the mother, one of them less markedly. Three of the girls resemble the father, the fourth resembles the mother only slightly. All have excellent health.

FREEMAN WEISS.
U. S. Dept. Agriculture.

A Note on Yellow Fatuoids[1]

IN a recent number of this Journal (20:66-70), Stanton and Coffman discuss the fact of finding yellow fatuoids, or false wild oats. They show that undoubtedly fatuoids do occur in yellow varieties of oats.

The question of doubt concerning yellow fatuoids seems to be due to the fact that certain observations by Nilsson-Ehle (*Ztschr. Ind. Abs. u. Vererb.* 12:36-55) and others have shown that the yellow color seems to inhibit the production of awns, and awns are one of the characteristics of fatuoids. It is true, as pointed out by Love and Craig (*Am. Nat.* 52:369-383) that yellow color, or some factor associated with it, in some cases does inhibit the production of awns, but, as stated in the writers' earlier paper, " . . . we do not intend to convey the idea that yellow color as found in oats will inhibit the production of awns, pubescence and base, but mean merely that the yellow as exhibited in this series (Sixty-Day variety) does that. In fact, we know from the crosses we have already studied where other yellow forms have been used that it is possible to obtain the yellow pubescent form and yellow ones with the wild base."

All yellow oats do not inhibit awn production and therefore it is only natural that yellow fatuoids should be found. The variety Golden Giant is yellow and awned, and when crossed with *Avena fatua* produces in F_2 plants with fully awned yellow kernels having the typical base of *Avena fatua*.

In the cultures at Ithaca, yellow fatuoids have been found and the writers have also found yellow wild (fatua-like) oats in fields in California.

The writers feel certain that the opinion of Jones (*Welsh Jour. Agr.* 3: 221-231) cited by Stanton and Coffman must be modified when all varieties or strains of yellow oats are considered. Certain, but not all, yellows inhibit awns, therefore one should find yellow fatuoids in some varieties and not in others. Since Stanton and Coffman found fatuoids in strains of Kherson it may be that the inhibition is limited to strains, as the writers found a strain of Sixty Day, considered by some to be the same variety as Kherson, showing the inhibitory effect.

As more fatuoids are found it will be interesting to note the comparative frequency of those found in yellow and white varieties and also what yellow varieties have thrown them.

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THE DRAKE POTATO INTRODUCTION MONUMENT

How the Small City of Offenburg, Baden, Happens to Possess the Only Monument to the Introducer of the Potato

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MOST of the pretentious books about the potato contain a reference to the heroic statue of Sir Francis Drake which stands in the principal street and market place of Offenburg in Baden. The recent series of articles by Safford in the *Journal of Heredity* for 1925 is accompanied by a full-page illustration of the Drake monument. (This is reproduced here on Page 175.) Nowhere is the exact significance of this memorial stated, although the implication is sometimes made that a grateful people are responsible for it, and not uncommonly a part of the engraving from the base of the monument is quoted in support of the idea. The legends, of which there are four, certainly lend strength to the assumption. As these have been misquoted, even the contemporaneous account in *Botanisches Zeitung** being slightly wrong, the exact wording as taken directly from the original is here set down. It reads as follows:

Front (South): "Sir Francis Drake Verbreiter der Kartoffel in Europa im Jahre des Herrn 1586".

East: "Der Segen von Millionen Menschen, die den Erdball bebauen, dem unvergänglichsten Nachruhm".

West: "Bitterem Mangel steuert die köstliche Gottesgabe als der Armen Hülfe gegen die Noth".

On the rear: "Dem Schöpfer und Stifter dieses Standbilds, Andreas Friedrich, aus Strasburg, der Dank, der Stadt Offenburg, 1853".

It says that Drake is the distributor or disseminator of the potato in Europe. Nothing is said about introduction; "the blessing of the millions of people who cultivate the potato to his immortal glory; this precious gift of God contributes to the stinging penury of the poor a help against misery." Certainly the wording supports the idea that a popular subscription might have been taken to express in a fitting way the gratitude of the people generally to one who was all too late recognized as a great benefactor of mankind.

How does it come that this statue of heroic proportions stands in Offenburg? The city is a small one with a population of perhaps 20,000, lying in the Rhine Valley on the Kinzig River and is a railroad junction point for travelers who enter the Black forest from the west. The surrounding country is a rich agricultural region, but potatoes are not a conspicuous crop and in fact are grown only for home consumption. The answer to the question can be found in "D'r alt Offenburger" of 22 July, 1900, in the long account of the dedicatory exercises published in the current newspapers particularly of Offenburg, in Gustav Mühl's little 20-page pamphlet entitled *Der elsässische Bildhauer Andreas Friedrich* (Strassburg, 1876), and especially in the oral explanation that any resident of the city gladly gives. In fact, the story of the shopkeeper, the man on the street, or the policeman on his beat is most helpful in interpreting the written record. The stories told to the writer do not vary in any important particular and taken in connection with the above-mentioned records can be relied upon as a fairly accurate statement of the facts.

*Vol. 12, page 832. 1859.

Andreas Friedrich (1798-1877) was an Alsatian sculptor who attained some distinction in his chosen field. He was first a student of anatomy. Then he studied successively under such well-known sculptors as Böttiger, Schadow, Bossio and Thorwaldsen. After years of travel and study he returned to Strasbourg where he was busy executing the commissions that he received—the colossal Turenne for the French government, fountains, cemetery statuary and statues for his native city and surrounding municipalities. In spare time he worked on special pieces which he hoped to sell when completed. The Drake statue is a case in point. Friedrich hoped that the city of Strasbourg would take the piece and erect it. It was offered to the city and was refused. It was offered subsequently to various cities and finally to Offenburg at a very favorable price. Friedrich gave the statue to Offenburg and in return was made a citizen of the city and was given an honorarium. The official thanks of the city fathers of Offenburg is preserved in a Strasbourg museum. The "fathers" state that they came by the statue "honorably". Friedrich is said to have imposed one condition, namely that the statue be erected with its back to Strasbourg. It is true at any rate that the statue stands in that position.

The connection of Sir Francis Drake with the potato remains obscure. The stories in the literature credit Drake with the introduction of the potato perhaps more often than they do Sir Walter Raleigh. Stories and songs about Drake are common in the Palatinate, and even the scientist, Sorauer, begins a song which he wrote in 1875 in the following words:

Als Franz Drake kam aus Chile
Und zur Wohltat für so viele
Die Kartoffel uns bescheert
Und auch mühevoll gelehrt
"Wie man sie soll kochen."

That Drake could have brought the potato to Europe is not a matter for doubt. His many contacts with Spanish vessels in South American trade, with the frequent necessity of taking food, as well as silver and gold, from the captured ships would make this a simple matter. The only question apparently is whether he did bring potatoes and if so whether others had not brought them previously. Drake's voyage around the world was begun in 1577. On November 28 he had rounded the Horn and had landed on an island, La Mocha, where the natives gave him among other things, potatoes. November would be in the spring of the year. Even if freshly dug tubers had been secured it is scarcely possible that they would have kept until he returned to England on November 3, 1580. Many of the "potatoes" mentioned by travelers were really sweet potatoes, but on La Mocha it is altogether likely that the solanaceous potato was encountered. It is surprising, therefore, that Clusius, who spent nearly a year in England and in intimate contact with Drake immediately upon his return from circumnavigating the globe, should not have heard of the potato. Clusius' *Aliquot notae in Garciae aromatum Historiam*, published is 1782, acknowledges in the subtitle that he got his information from Francis Drake. When Clusius received a sample of potato tubers at Vienna in 1588 he wrote a lengthy description of tubers and plants which finally was published in his *Rariorum plantarum historia* (1601), but in which no mention is made of Francis Drake nor for that matter of John Hawkins, with whom he also had been on intimate terms on an earlier visit in England.

Drake's next voyage was undertaken in the year 1585 and was terminated at Portsmouth July 28, 1586. This is the date mentioned on the statue. Here again it is possible that Drake took potatoes from captured vessels. He left England in September, 1585, and plundered vessels and cities in the West Indies throughout the winter. The chances of finding potatoes in such captured vessels, however, must be regarded as rather remote. These vessels were plying from Nombre de Dios, a

THE DRAKE MONUMENT AT OFFENBURG

Figure 15

Sir Francis Drake holding a potato with its tubers attached. This monument stands in Offenburg, Baden, in commemoration of his alleged introduction of the potato into Europe.

The inscription on the statue reads: "Sir Francis Drake, introducer of the Potato into Europe, in the year of our Lord 1586." Note the potato plant in Drake's hand and the decorative frieze of potatoes around the base of the statue.

From a photograph received through the kindness of Dr. Otto Appel, of Berlin-Dahlem.

Reprinted from "The Potato of Romance and of Reality," *Journal of Heredity*, Volume 16.

Caribbean port, to which place potatoes would have to be portaged across the isthmus. Since the Spaniards were not accustomed to the potato it is unlikely that they would have included the tubers in ships provisions, or, for that matter, it is rather unlikely that any potatoes could have been bought in the market of Nombre de Dios at all. Cates in his *Summary and True Discourse of Sir Francis Drake's West Indian Voyage* describes the gardens about the captured city Santiago and mentions specifically that "potato-roots" were grown. Considering the lemons, oranges, sugar canes, plantains, etc., which are found in these gardens, it is to be inferred that these potatoes were really sweet potatoes. Drake cruised northward and on June 18 picked up Martin Lane and the remnant of Sir Walter Raleigh's ill-fated colony at Roanoac. Thomas Hariot's account leaves no doubt that solanaceous tubers were not found in "Virginia" by this colony and the manner of leaving practically precludes that any plant specimens were taken, although it is claimed by some that Lane took tobacco to England at this time.

It appears, therefore, that the Offenburg monument of Francis Drake has no significance so far as the potato is concerned nor so far as potato growers are concerned. It does have significance in helping to perpetuate an interesting legend, but more important, especially coming from a native of war-ridden Alsatia, it does memorialize in a fitting way the debt that millions of men do owe to the introducer of the potato. The credit for expressing this debt in a very fitting manner belongs to the Alsatian sculptor, Andreas Friedrich.

The Long-Lived "Immortals"

The members of the various academies composing the Institut de France have been honored, in ordinary speech, with the metaphoric appellation "the immortals," which dates from the "romantic period" in which the institute was created, and which is still employed. Prof. Charles Richet, who is 86 years of age, has presented to the Academy of Sciences, of which he is the dean, a communication on the "age of the immortals." He has taken the trouble to figure out whether the title of academician constitutes also a title to longevity. The average age at which savants are elected to membership in the institute is 50 and, of late, has approached 55. According to the mortuary tables, the average expectancy of persons who have passed the fiftieth year is twenty-one years. Seventy-one is the average age of the academicians. The institute is comprised, for the most part, of elderly men. They are men of science who have finished their careers, and who are now living quiet lives under peaceful conditions.—*Jol. Am. Med. Assoc.,* Vol. 92, No. 16, Page 1367.

CRYPTIC TYPES IN DATURA

Due to Chromosomal Interchange, and Their Geographical Distribution*

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IN presenting some of the things we have learned about the behavior of chromosomes in Datura, it will be convenient to make use of diagrams and models.† Figure 16 represents the chromosomes at the stage in reduction division when homologous chromosomes are joined together in pairs. Six size classes have been determined by Belling, the size formula being: $1L + 4l + 3M + 2m + 1S + 1s$. Dr. Bergner has recently discovered that one of the small medium chromosomes has a distinct hump (m°) so that at least five (L, m, m°, S and s) can be identified under the microscope. We will center our discussion upon two chromosomes, the largest (L) which for convenience may be called the white chromosome, and the small medium one without the hump (m), which is stippled in the diagram, and will be called the stippled chromosome. One-half of each of these chromosomes has been shaded to distinguish it from the other half. The outer ends of each half are marked by a black dot. The chromosomes of the other ten sets are shown merely in outline and need not concern us in the present discussion.

Before discussing the make-up of the chromosomes in other races in nature, it will be well to review briefly some of the facts known about the chromosomes in our Line 1, a highly inbred race which has been used as a standard. A general discussion of chromosomal mutants in Datura has been given in an earlier number of this journal.[5] Figure 17 shows a normal Line 1 plant which may be compared with the other types in the figures, all of which were photographed from the same distance.

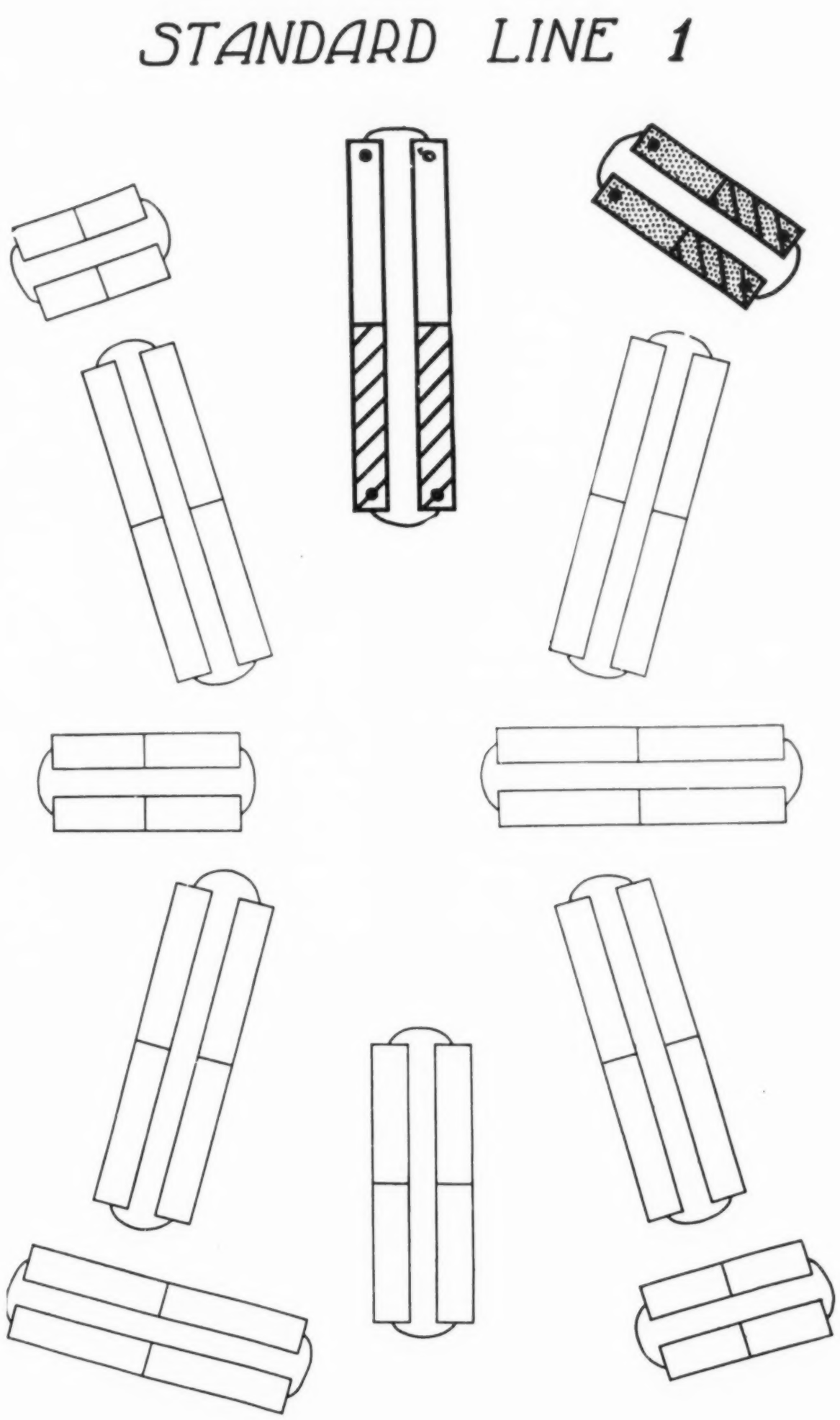
If to the set of two white chromosomes of Line 1, an extra member like the other two is added as shown by the models (Figure 19), we have a ($2n + 1$) type of distinct appearance represented by our "Rolled" mutant. From the peculiarities of this type we may learn something about the aggregate of factors contained in the white chromosomes. A type, named Sugarloaf, is known in which the chromosome added to the white set consists of two unshaded halves joined together as shown in Figure 18. The characters of the mutant type which results tell us something about the factors in the unshaded half of the white chromosome. A type, named Polycarpic, complementary to that just discussed, has the extra chromosome made up of two shaded halves (Figure 20). This type gives us information regarding the factors in

*Invitation paper presented before the joint session of Section G of the A.A.A.S. and the Botanical Society of America, December 28, 1928.

†The models were wooden blocks about 2 inches wide and ½ inch thick on which were mounted cardboard strips marked with black and red to represent respectively the L and the m chromosomes of Line 1. An easel faced with a soft composition building material called insulite served as a background to which the models were attached by means of phonograph needles which had been driven through the blocks and sealed at their blunt ends with shellac. The editor of the JOURNAL OF HEREDITY has brought to our attention a mechanical toy—"Mysticks"—sold by the LaVelle Mfg. Co. of New Haven, which seems beautifully adapted to demonstration of chromosome behavior. It consists of a sheet iron blackboard with a set of small bar magnets painted in different colors which can be shifted on the iron blackboard as desired.

the shaded half of the white chromosome.

A type with the extra chromosome like the other two in the set is called a primary type in distinction from secondary types, in which the extra chromosomes have been formed apparently by a breaking into two of a normal chromosome and a joining together of like halves. In the models we have not shown how the chromosomes in the trisome or set of three are attached together in the reduction divisions. Figures 18, 19 and 20 show the appearance under he microscope of the chromosomes of the primary and the two secondaries of the white set. Those of Rolled and Sugarloaf are taken from Belling's figures, those of Polycarpic were drawn by Dr. Bergner. Since like ends may become attached, the trisome of secondaries may form a closed ring of three but the chromosomes of a primary never can form such a closed configuration.



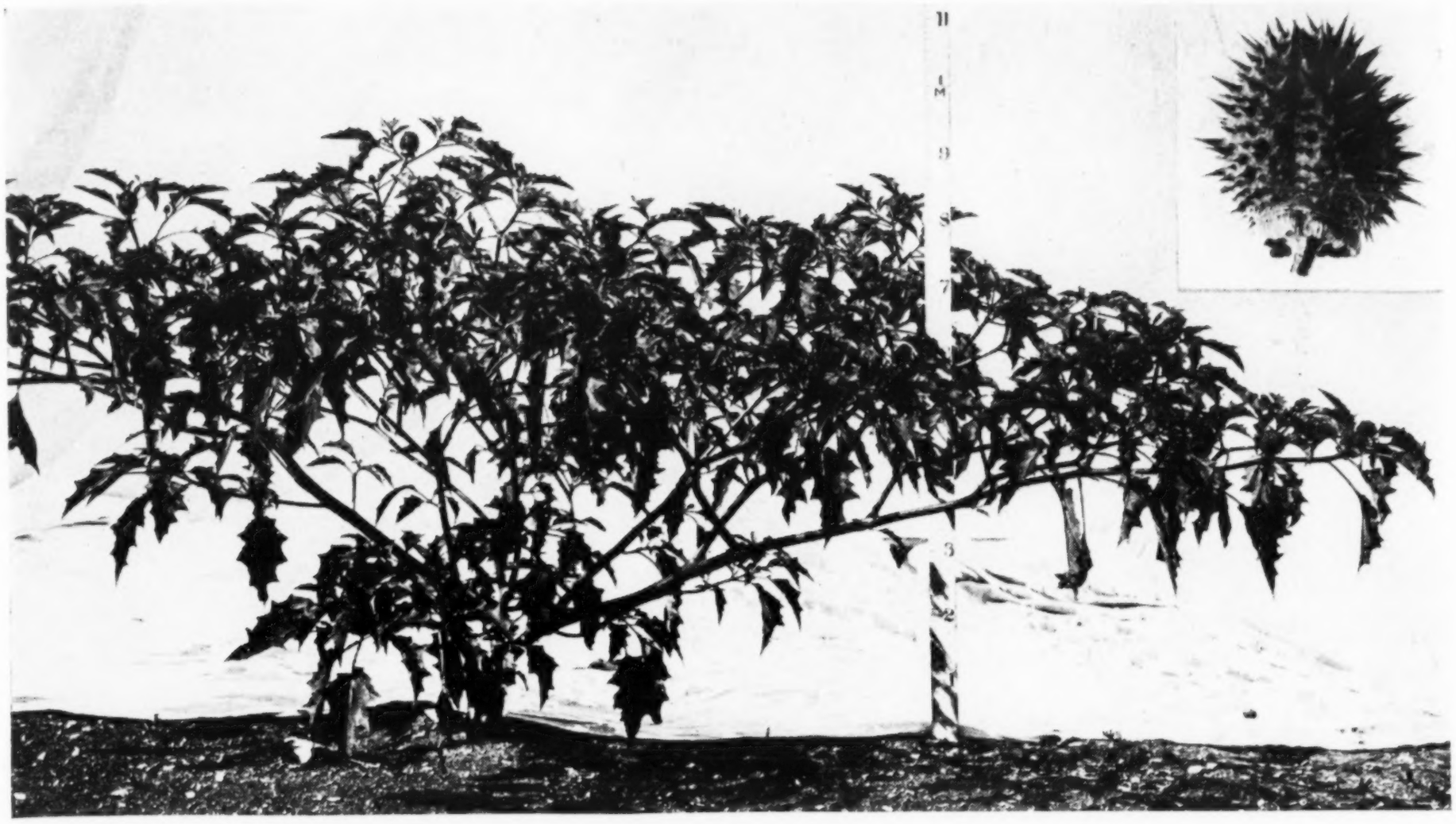
"STANDARD" CHROMOSOMES OF DATURA

Figure 16

Diagram of chromosomes in a normal Datura plant of standard Line 1. The chromosomes are in pairs and show six size classes represented by the formula:—*2*(1*L* 4*l* 3*M* 2*m* 1*S* 1*s*). The largest (*L*) and a small medium (*m*) chromosome are shown with one half shaded by cross lines and the other half left unshaded. The *m* chromosome is shown stippled to distinguish it from the white *L* chromosome. The behavior and effects of these two chromosomes are discussed in the present paper. The other chromosomes are represented in outline only.

Effects of Extra Parts of Chromosomes

If we compare the primary Rolled with its two complementary secondaries, Sugarloaf and Polycarpic —all three the result of single extra chromosomes in the white set—we will note that each secondary is extreme in certain characters while the primary is intermediate. Thus, to mention but a single character, in Sugarloaf the capsule is large, a peculiarity due to the unbalance brought about by two extra unshaded halves of the white chromosome. In



PLANT OF LINE 1

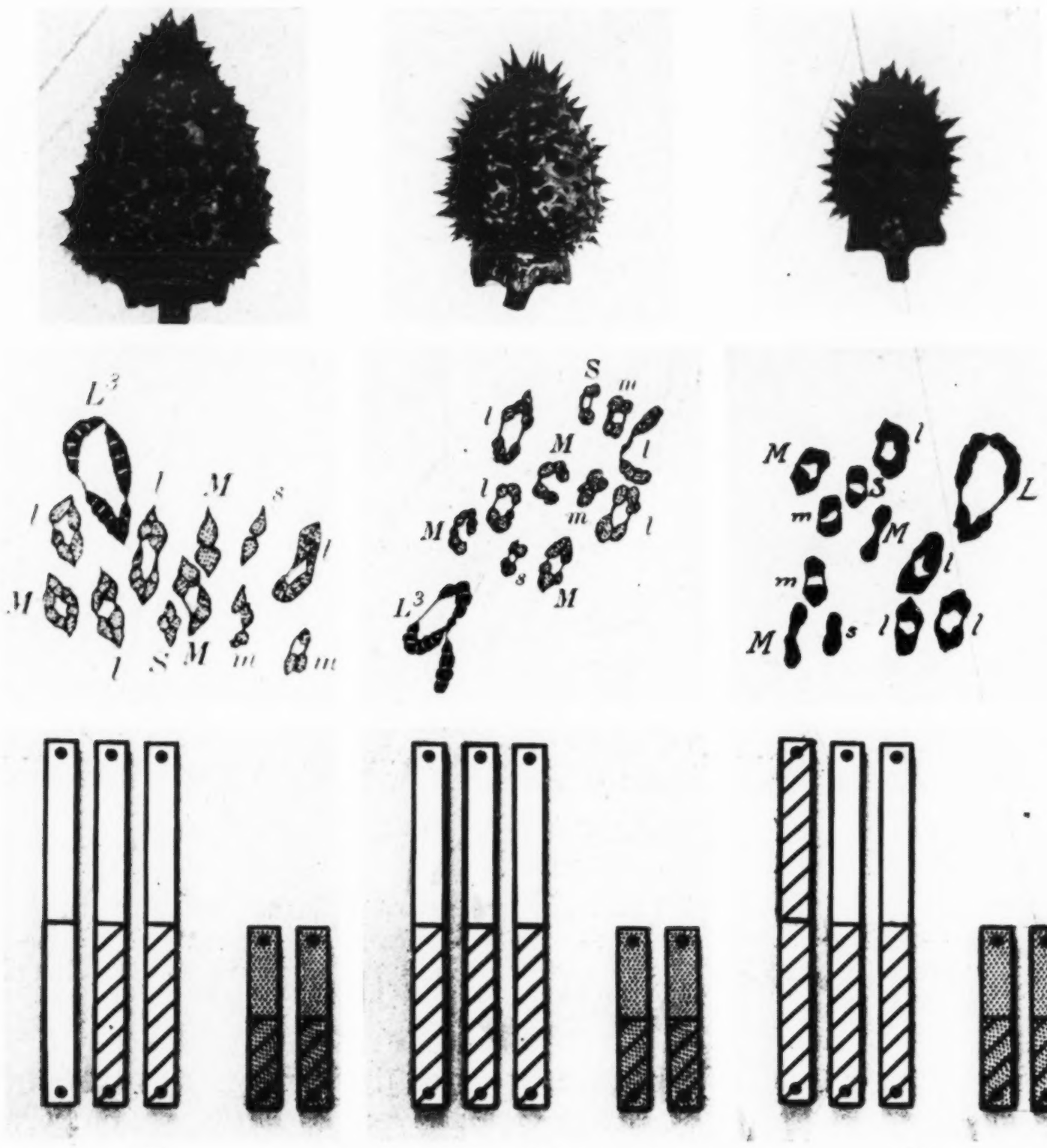
Figure 17

A normal field-grown plant of Line 1 together with insert of a capsule, the latter slightly less than half natural size. All the photographs of plants in this paper are reproduced to the same scale as is also true of the capsules. A diagram of the chromosomes of the normal type shown in this figure is given in Figure 16.

Polycarpic, the other secondary, the capsule is small, a fact resulting from the presence of two extra shaded halves. The primary Rolled, having extra both the shaded and the unshaded half of this same white chromosome, is intermediate in capsule size and shape. Photographs of Rolled and its two secondaries have been published elsewhere.[3]

In a similar manner we have a primary type called "Poinsettia" (Figure 21) due to an extra stippled chromosome and a secondary type called Dwarf (Figure 22) due to the presence of an extra made up of two shaded halves of the stippled chromosome. The secondary with an extra made up of two unshaded halves of the stippled chromosome has not yet been discovered. Possibly it is not viable. From the characters of the primary we know something of the factors in the whole stippled chromosome and from the characters of the single secondary, we know something of the factors in the shaded half. By subtraction, we can gain some idea of what characters the missing secondary should show when discovered and hence of what the factors are in the unshaded half of the stippled chromosome.

When the chromosomes are in sets of two or disomes, we have the ordinary disomic ratios expected in Mendelian inheritance. When, however, the factor in question is in a trisome or set of three chromosomes, other ratios, called trisomic, result from parents hybrid for a given character. It will be out of place to discuss such ratios further. It will be sufficient to state that the occurrence of trisomic ratios has been used to locate factors in the particular chromosomes in which they belong. Thus we early concluded that the factors for purple and white flower color were in the stippled chromosome just discussed since plants with this chromosome extra, when they were hybrid for purple and white, produced trisomic ratios in their offspring



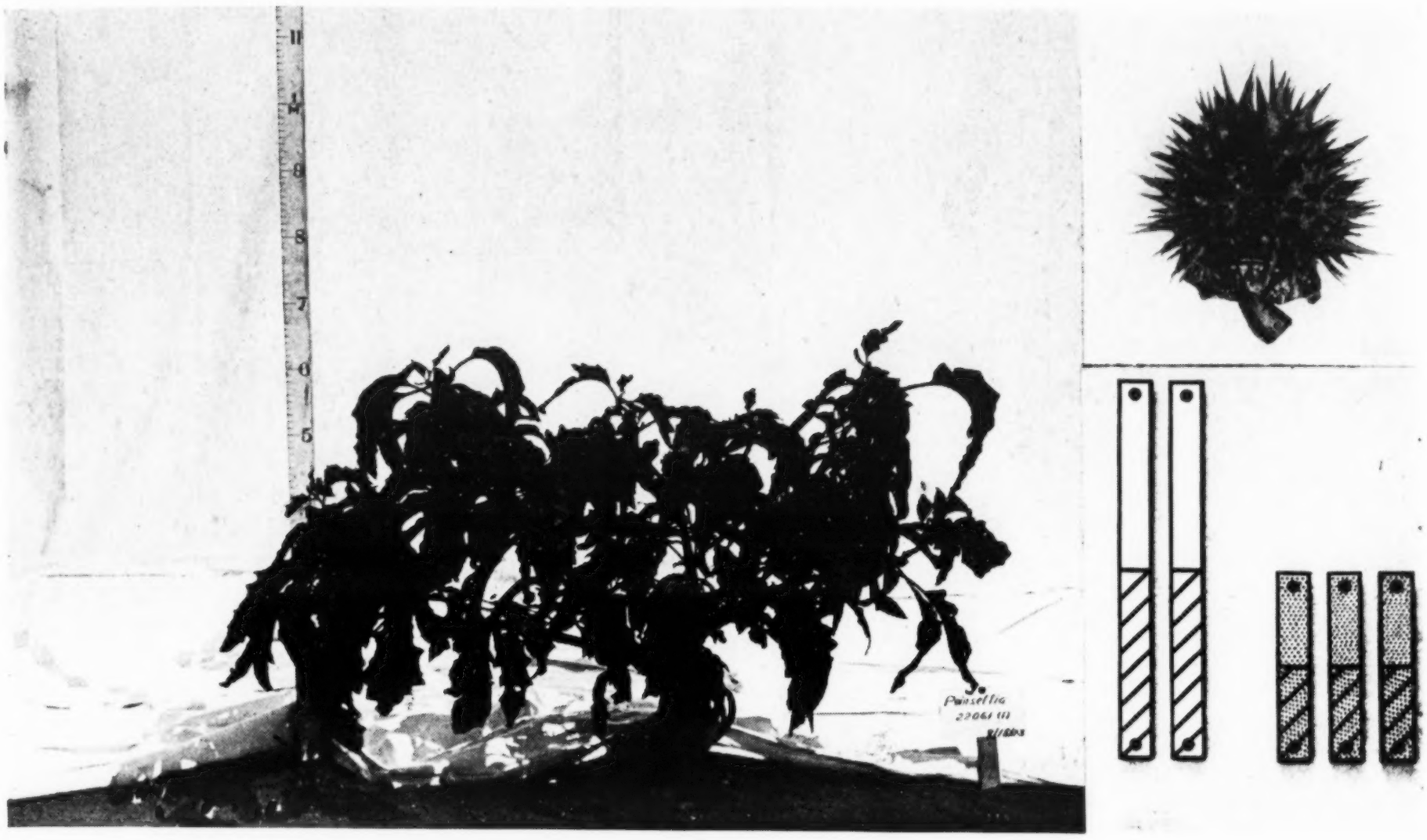
18 19 20

PRIMARY AND SECONDARY EXTRA-CHROMOSOME TYPES

Figures 18, 19 and 20

Upper row—capsules; *middle row*—drawings of actual chromosomes as seen under the microscope; *lower row*—models of the *L* and *m* chromosomes of the three related chromosomal types "Rolled," "Sugarloaf" and "Polycarpic," each of which has a large *L* chromosome extra. In the primary type, Rolled (Figure 19), the extra chromosome is like the other two large *L* chromosomes and the three are attached together but never form a closed circle of three members. In the secondary Sugarloaf (Figure 18), the extra *L* chromosome is made up of the unshaded half doubled, and the complementary secondary Polycarpic (Figure 20), the extra is made up of the shaded half doubled. The three large *L* chromosomes in these secondaries can become attached by like ends to form a closed circle of three as shown in the drawings. The secondary Sugarloaf has a large pointed capsule, a peculiarity due to the unbalance brought about by two unshaded halves of the *L* chromosome; the complementary secondary Polycarpic has a small rounded capsule resulting from the presence of two extra shaded halves. The primary type Rolled, having extra both the shaded and the unshaded half of the *L* chromosome, is intermediate in capsule size and shape.

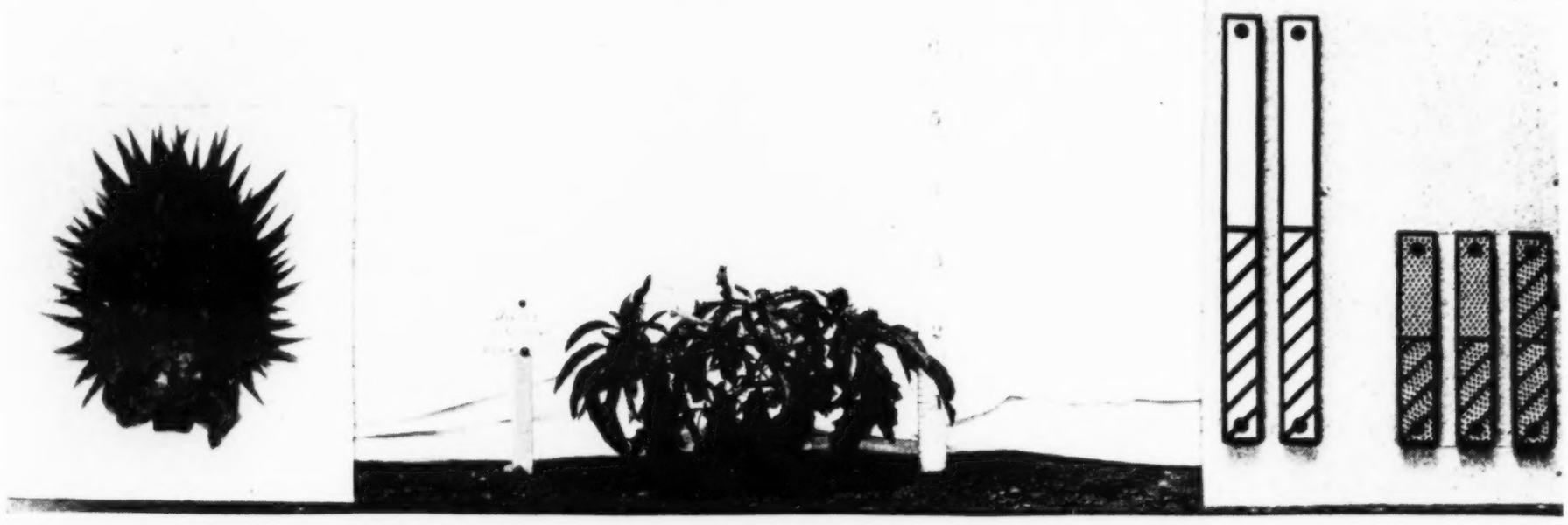
but types with any other chromosome as an extra produced ordinary disomic ratios. This was found to be true in extensive tests with certain white races from this country called *A* whites. Other races called *B* whites gave trisomic ratios from hybrid parents, not only when the stippled chromosome was the extra but also when the white chromosome was the extra. A further relation between the white and the stippled chromosomes in these *B* whites was shown by an extra chromosomal type called Wiry (Figure 23), which was produced by the type with the *m* chromosome extra, but only when this type was hybrid for a *B* white. Wiry



PRIMARY *m* CHROMOSOME TYPE

Figure 21

Primary chromosomal type "Poinsettia," mature plant, capsule and models. The characteristics of this type are brought about by the presence of an extra stippled (m) chromosome.



"DWARF"—A SECONDARY TYPE

Figure 22

A secondary type "'Dwarf," showing mature plant, capsule and models. The extra chromosome, which determines the peculiarities of this type, consists of the shaded half of the stippled (m) chromosome doubled. See Figure 21 for the primary of this secondary.

was seen to be related to both the types in Figures 20 and 21. From our knowledge of the factors in the halves of the two chromosomes we have been discussing, it was evident that Wiry was related in some way to the shaded half of the white chromosome and to the unshaded half of the stippled chromosome. Another extra chromosomal type appeared from parents hybrid for *B* races and was called Dwarf Sugarloaf (Figure 24) from its resemblance both to the Sugarloaf type (in which the extra has the unshaded half of the white chromosome doubled) and to the Dwarf type (in which the extra has

"WIRY"—WITH AN INTERCHANGED EXTRA CHROMOSOME
Figure 23

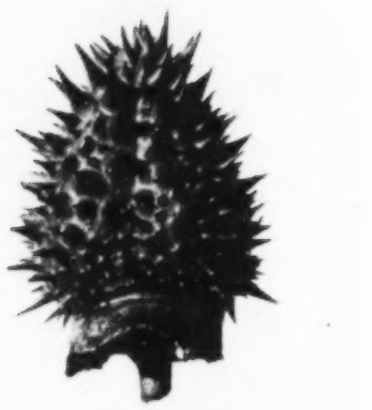
The tertiary type "Wiry" showing plant, capsule and models. The extra *m* chromosome, which causes the peculiarities of this type, is made up of the unshaded half of the stippled chromosome united to the outer portion of the shaded half of the white chromosome. This extra chromosome represents the *m* chromosome of the "*B*" race (See Figure 25).

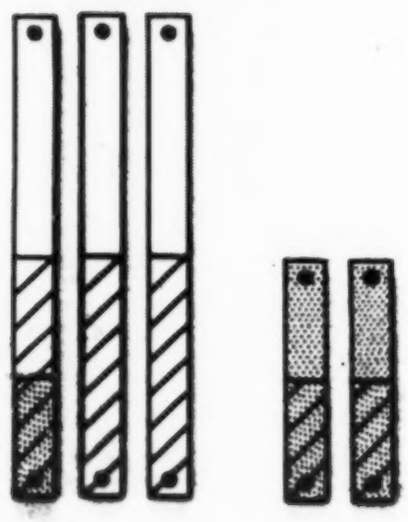
the shaded half of the strippled chromosome doubled).

An investigation of the chromosomes of Wiry made by Belling[2] showed two large (*L*) chromosomes attached to a small medium (*m*) chromosome. Since attachments are between like ends, it was concluded that one end of an *m* chromosome was homologous with one end of an *L* chromosome. From these findings he proposed the hypothesis of interchange between segments of these non-homologous chromosomes to account for the origin of *B* races from the standard type. The chromosomal diagram of such *B* races is shown in Figure 25. It will be noted that all except the white and the stippled chromosomes are the same as those in our standard line 1 (Figure 16). There is no necessary difference between the two races, in respect to the factors which these chromosomes contain. The grouping of these factors merely is changed.

Formation of Chromosome Rings

It occurred to us that if the chromosomes of Line 1 and a *B* race were really made up in the manner indicated in Figures 16 and 25, the hybrids between these two ought to have the *L* and the *m* chromosomes attached together to form a closed configuration of four members[4]. The configurations of these chromosomes actually found in the hybrids were those anticipated on the basis of attachments between like ends, and are shown in Figure 26. Further tests of the hypothesis were made by noting the effects of extra chromosomes on the circle of four. By crossing a *B* race onto a Line 1 type with an extra stippled chromosome (Figure 21) we can add a stippled chromosome to the circle of four of Figure 26. When this is done, the closed circle of four is broken and transformed into a chain of five members as shown in Figure 27. If, however, we make a secondary, such as that in Figure 18, hybrid for a *B* race, we are adding a double half chromosome and thereby keep the circle closed though increasing it to five members, as shown in Figure 28. The circle of four and these two modifications

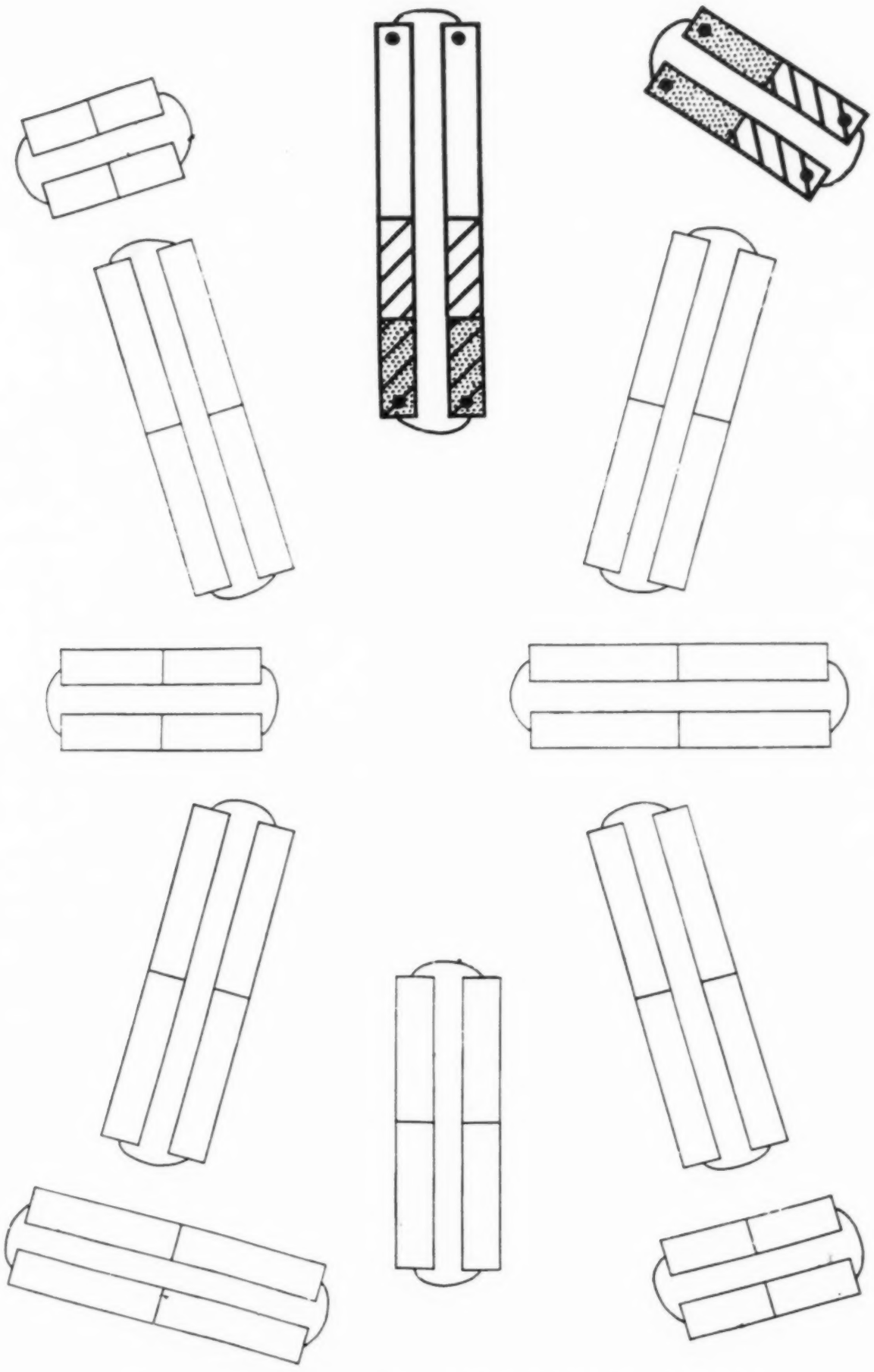




"DWARF SUGAR-LOAF" WITH AN INTERCHANGED LARGE CHROMOSOME EXTRA

Figure 24

The tertiary type "Dwarf - Sugarloaf," showing capsule and models. The lower part of the extra *L* chromosome consists of the shaded half of the stippled chromosome. It is the large *L* chromosome of the "B" race (See Figure 25).



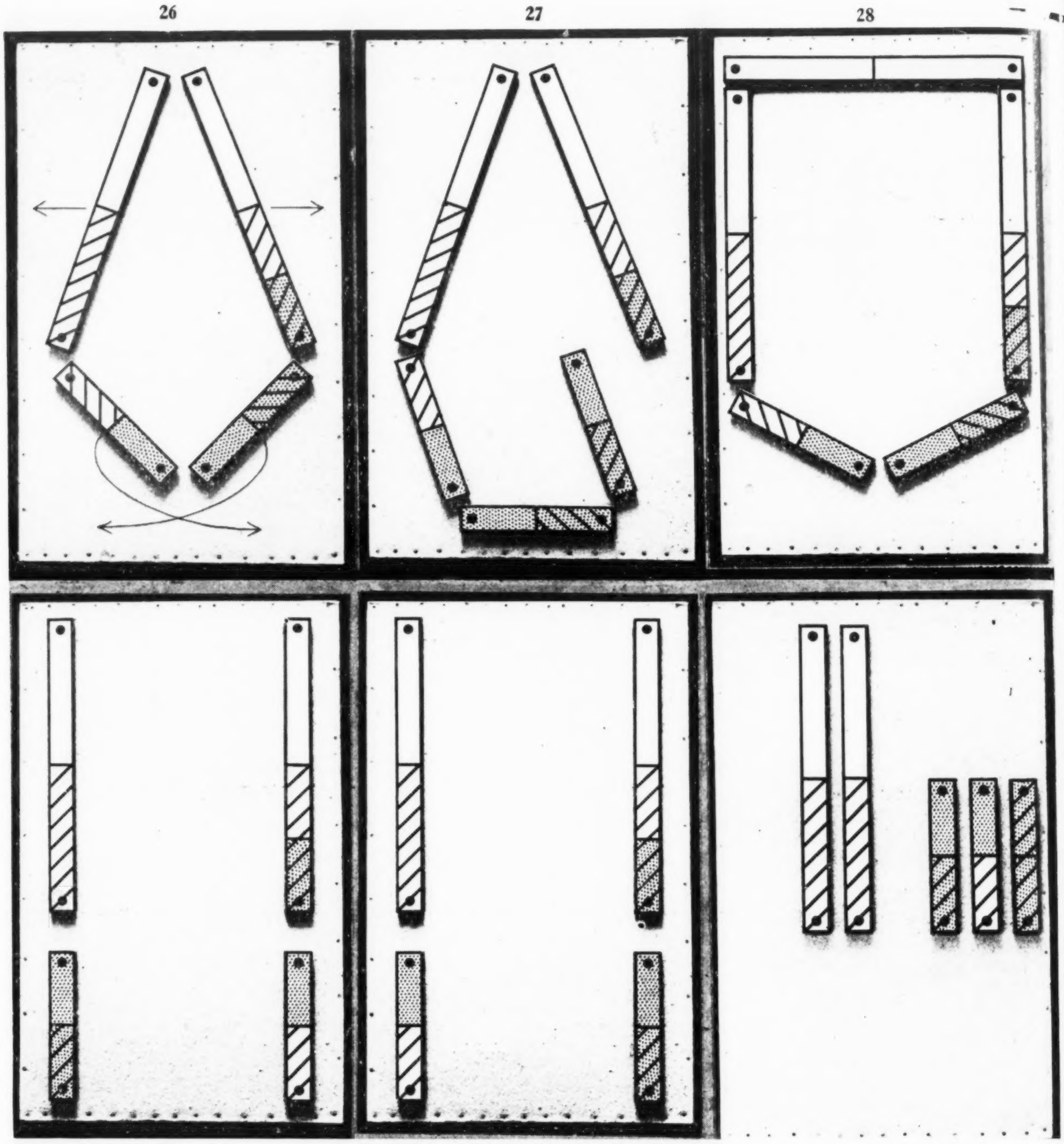
Chromosomal Formula: 2(1L+4l+3M+2m+1S+1s)

DIAGRAM OF CHROMOSOMES IN THE "B" RACE

Figure 25

The chromosomes are the same in appearance and together represent the same amount of chromosomal material as those of Line 1 shown in Figure 16. They differ, however, in the constitution of the individual *L* and *m* chromosomes, which in the "B" race are made up as if the shaded half of the stippled (*m*) chromosome of Line 1 had changed places with the lower part of the shaded half of the large *L* chromosome.

just discussed do not change the external characters of the types affected since crossing with race *B* has the same visible effect upon the hybrids produced as crossing with Line 1. The reason for this is that an *L* + an *m* chromosome from Line 1 contain the same sum of factors as an *L* + an *m* chromosome from race *B*. When the *L* and the *m* chromosomes of race *B*, however, appear as extras, two new (2n +1) types should be produced. These have been found and are shown in Figures 23 and 24. They would show the same external characters if an *L* and an *m* from race *B* replaced an



MODELS SHOWING L AND m CHROMOSOMES

Figures 26-31

Figure 26 shows the *L* and *m* chromosomes in a hybrid between Line 1 and the "B" race. Arrows indicate the directions in which the chromosomes would separate in the formation of sex cells on the assumption that like ends repel each other in this stage of cell division. Figure 29 shows the result of the separation bringing about two kinds of sex cells like those of the original two parents (Line 1 and Race "B"). Figure 30 shows the results if the *L* and *m* chromosomes of the hybrid failed to separate as indicated by the arrows in Figure 26. The sex cells containing the *L* and *m* chromosomes at the left would abort, since they would lack a shaded stippled half, while those at the right would abort because they lacked a part of the shaded half of the white chromosome. Since there is no unusual amount of pollen abortion in hybrids between Line 1 and the "B" race, the type of separation shown in Figure 30 is believed not to occur in such hybrids. Figure 27 shows configuration of chromosomes resulting from the addition of an entire stippled chromosome to the circle of Figure 26. The circle is broken and a chain of five members results. Figure 28 represents a configuration of chromosomes resulting from the addition of a double-half unshaded white chromosome to the circle of Figure 26. The closed circle is retained, but increased to five members. Figure 31 is a diagram of a compensating type in which the unshaded stippled half of an *m* chromosome from the race "B," together with half of the double-half stippled chromosome, make up the equivalent of a Line 1 *m* chromosome, leaving, as extra chromosomal material to bring about the peculiarities of the plant affected, a shaded stippled half of *m* plus the outer portion of the shaded white half of *L*.

L and an *m* chromosome from Line 1. The same would be true if all the chromosomes were from race *B*. In the latter case they would be the primaries of race *B*.

There is at least one other extra chromosomal type shown in Figure 31 that might be expected. In this combination, the double-half shaded *m* chromosome + the *m* chromosome of race *B* together make up the equivalent of a complete stippled *m* chromosome of Line 1, leaving over a shaded stippled half and a shaded white quarter chromosome to influence the external appearance of the plant affected. Such a type involving the white and stippled chromosomes we have not yet discovered, but have made matings which we hope may cause it to appear. We have, however, found what we interpret as a similar type involving the combination of a secondary of Line 1 with another interchanged chromosome.

Chromosomal Repulsion

When the hypothesis of segmental interchange was proposed[2], it seemed to necessitate the abortion of half the pollen grains and ovules in hybrids between Line 1 and race *B*. If, in reduction divisions, the chromosomes should separate as indicated by the arrows in Figure 26, pollen grains with the full complement of vital factors should be formed (Figure 29) and there would be no abortion. If, however, the chromosomes should separate as in the manner shown in Figure 30, the pollen grains produced would abort since they would lack factors necessary to their existence; the two chromosomes on the left would lack a shaded stippled half, while the two chromosomes on the right would lack a part of the shaded white half. If separation of chromosomes were at random, there would average as many of the type shown in Figure 29 as of that shown in Figure 30 and 50 per cent abortion of pollen would result. Hybrids between Line 1 and *B* races have good pollen. Some cause preventing random separation of chromosomes from a closed circle of four, therefore, seems to be necessary. Although cytologists tell us that not enough is known of the dynamics of cell division to account for the behavior of chromosomes at reduction, we have ventured to suggest that like parts are repelled at separation. If this were true, the two large chromosomes in Figure 26 would separate because they both have unshaded white halves. The stippled chromosome on the right would be repelled to the left side because of its shaded half which is like that in the large chromosome adjacent. For similar reasons the *m* chromosome on the left would be repelled to the right. When the separations were complete, we would have the two original types restored, the Line 1 on the left and the *B* race on the right and no nonviable combinations would result. The idea of repulsion may serve to visualize what appears to happen but need not be taken too seriously as an explanation of the mechanism of nuclear division. Whatever the cause of the movements, it is an observed fact that normally at reduction homologous chromosomes are first attracted together in pairs with their like ends adjacent and that later these homologous chromosomes are separated to opposite poles. We are merely extending this behavior to parts of chromosomes and drawing conclusions as to the results which such a type of separation would bring about.

Since there are two kinds of sex cells in these hybrids, half of their offspring have circles of four and half have only paired chromosomes—the latter class equally divided between the Line 1 and the *B* types. There is clear evidence that interchange of some kind takes place in a circle of four chromosomes, but further study will be necessary to be certain that it is of the nature of crossing-over of factors between paired chromosomes.

Distribution of Types

As soon as it was learned that there were two types of whites, an investi-

gation was made of the various races in our collection to discover something about their occurrence in nature. Breeding tests by means of types containing the white and the stippled chromosomes as extras and especially by means of a compound chromosomal type, Nubbin[3], showed that both purple and white races which showed inheritance behavior similar to our original *B* race were common in nature. Later, after chromosomal interchange was seen to be a possible explanation of such *B* races, and the closed circle of 4 attached chromosomes in hybrids between these races and our standard line was found to be a characteristic of such races, it seemed desirable to study the configurations in hybrids with as large a number of races as possible to discover if other chromosomes had become involved in segmental interchange in their evolution.

With the aid of Dr. Bergner, who has been in charge of this phase of the work, Miss Satina, Dr. Jennie S. Simpson, Miss Rachel Haynes, Miss A. Johanson, Miss Louise Buck and Miss M. Chambers, it is possible to present the results shown in Table 1. The first column under chromosomes gives the number of races which showed 12 pairs (bivalents) in hybrids with Line 1. The second column gives the B races which showed in hybrids 10 pairs plus a *B* ring of 4 chromosomes ($L + m$). Those in the third column showed, in hybrids, 8 pairs plus a *B* ring plus a smaller ring of 4 involving two other chromosomes. The fourth and fifth columns include races which induced in hybrids configurations of 4 attached chromosomes different from those in the previous columns, while in the last column are included other less common configurations. It should be stated that this classification is a preliminary one only and will doubtless need to be changed with further study. For example, among the types listed as inducing rings are some for which only chains have as yet been observed.

Chains, instead of circles, might be due to the reversal of a segment in the process of interchange so that an end was turned in and could not become attached to the corresponding segment in the ancestral line. Races which induce chains may have originated without segmental interchange by the translocation of a fragment from one to another chromosome.

It is possible also that the order of the attached chromosomes may be significant. Further, it should be remembered that it is not possible in all cases to be certain of the specific chromosomes in a configuration from their sizes alone. Thus there are four chromosomes in the size *l* class. When the chromosomes cannot be determined microscopically, it has been possible, by crossing races which induce configurations onto Line 1 types with extra chromosomes, to identify the chromosomes which have undergone segmental interchanges from the attachments which result (cf. Figures 27 and 28) and from the new extra chromosomal types which they produce. Linkage with genes in specific chromosomes has also been of assistance. We have thus identified the four $l + S$ chromosomes involved in the small ring induced by races from Peru and, for one of the races in the next to the last column, have identified the *l* chromosome involved in the segmental interchange and found it to be a different one from the one in the ring induced by the Peruvian races just mentioned.

When the chromosomes of races which induce special configurations have been determined, these races may be used as testers. Races of the same chromosomal type when crossed together produce hybrids with all the chromosomes in pairs.

The data presented in Table 1 are far from being an adequate sample of the races in nature but are sufficiently extensive, we believe, to warrant some general conclusions. So far as the analysis has gone, it seems to indicate that there are relatively few groups into which the chromosomal types can be arranged. Except for the

TABLE I

DISTRIBUTION OF POLLEN & CHROMOSOMAL TYPES (209 RACES)
CONDITION IN F_1'S WITH LINE 1

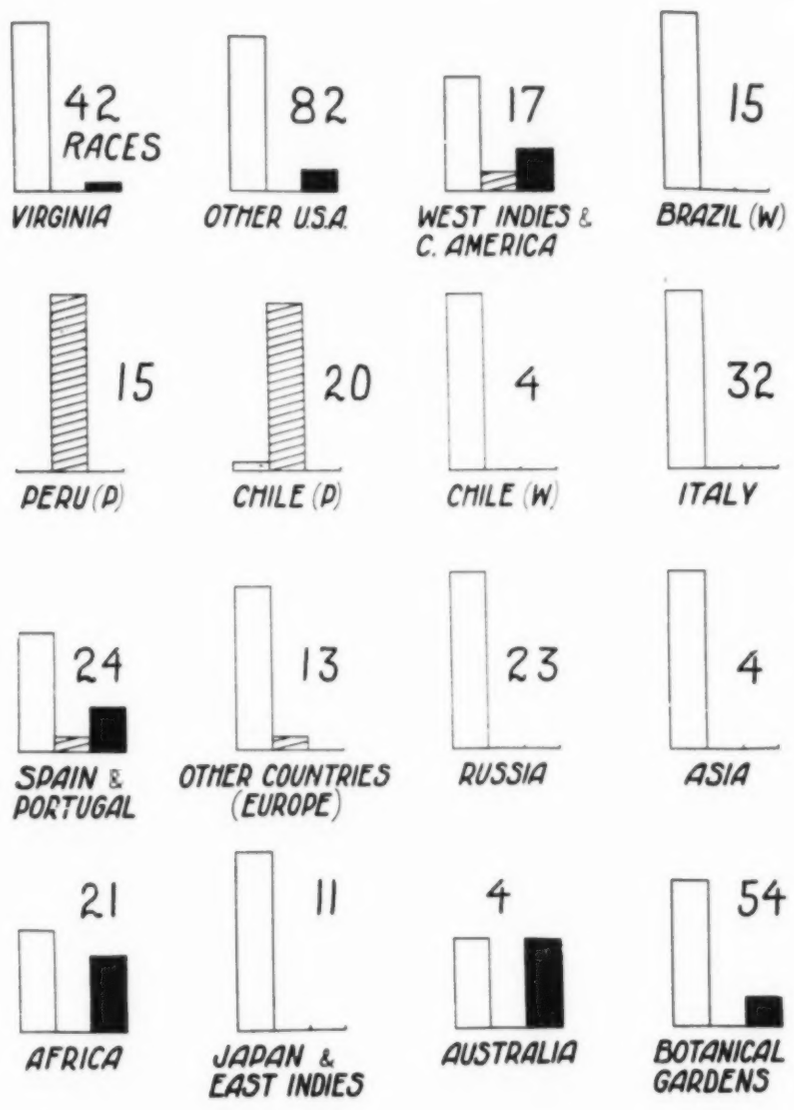
NO. RACES	ORIGIN	POLLEN			CHROMOSOMES					
		O.K.	25%	50%	12 Bivalents ○	10 Bv+1 RING ○ (L+m)	8 Bv+2 RINGS ○ (L+m) ○ (l+S)	10 Bv+CHAIN / (M+S)	10 Bv+1 RING ○ (l+m)	OTHER CONFIGS.
31	VIRGINIA	29		2	17	2	2	1	9	1 ⊖ L+M
59	OTHER U.S.A.	50		9	56	2				
11	WEST INDIES & C. AMERICA	6	1	4	3	3	1	1	3	
4	BRAZIL	4			4					
8	PERU (P)		8			1	7			
5	CHILE (P)		5				5			
2	CHILE (W)	2				1				1 ○ L+l+m
7	ITALY	7				5	2			
11	SPAIN & PORTUGAL	9	1	1	1	1	9			
8	OTHER COUNTRIES (EUROPE)	8			3	5				
10	RUSSIA	10				10				
1	ASIA	1								1 V L-M+m
12	AFRICA	6		6	1	5	1		5	
8	JAPAN & EAST INDIES	9			2	6				
3	AUSTRALIA	2		1		1			2	
29	BOTANICAL GARDENS	27		2	8	17	1		3	

CHROMOSOMAL FORMULA: 2(1L+4l+3M+2m+1S+1s)

TABLE II

DISTRIBUTION OF POLLEN TYPES (381 RACES)
DETERMINED BY
POLLEN ABORTION IN F_1'S WITH LINE 1

GRAPHS SHOW PERCENTAGES IN EACH CLASS
□=O.K. ▨=25% ABORTED ■=50% ABORTED



few races in the last column, no higher number than four chromosomes have been found attached in hybrids with our standard line. The configurations of six may be due to a secondary interchange.

So far as the distribution of types is concerned, it will be noted that the type represented by our standard Line 1 is the most common one in this country. With the exception of Brazil, from which only four races have been tested, it is not, however, the predominant type in other countries. The *B* type, which we have earlier discussed, is by far the most widely distributed. In Russia it is the only type yet identified. The Peruvian races and the purple flowered (P) races from Chile, induce in hybrids with our standard line not only a *B* ring but a second smaller ring involving other chromosomes. If primary (2n + 1) types were obtained from Peruvian lines, there would be, therefore, four of the 12 primaries which differed from those obtained from our Line 1. It is evident that the evolution suggested by segmental interchange may have proceeded from the more common *B* types to our standard Line 1 type as well as in the reverse direction.

If either end of the *L* and the *m* chromosomes can take part in segmental interchange of the type just discussed, there are 13 different kinds of these two chromosomes that can be expected, as shown in Figure 32. This figure will serve to show the shorthand method we are accustomed to use in making up chromosomal diagrams, with the exception that solid and dotted lines replace the black and red pencil marks assigned to the *L* and *m* chromo-

somes of our standard Line 1. The crossed end has been called the + in distinction from the opposite or – end. In the upper row are shown the chromosomes which are supposed to have interchanged their terminal segments as indicated by the arrows. In the lower row are shown the constitutions of the two chromosomes which result from the interchange. Types with the *L* and *m* chromosomes represented by B, B^1, B^2 and B^3 would induce rings of four chromosomes in hybrids with Line 1. Hybrids with B^4 and B^5, however, should have these chromosomes paired, *L* with *m*. Of the 13 different kinds of chromosomes represented in Figure 32, the *m* chromosomes of B^4 and B^5 are alike in the factors which they contain and in the arrangement of these factors. Their *L* chromosomes are alike in the factors but not in the arrangement. They could not be distinguished, therefore, by the effects produced if they were present as extras. If a secondary were formed with its extra made up of one of the halves of an *L* chromosome doubled, it would have a different appearance according to whether it came from the B^4 or the B^5 type. We have become familiar with the effects produced by different chromosomes and portions of these chromosomes, due in no small measure to the keen discrimination of Mr. A. G. Avery. The morphological characters of a plant with an extra chromosome, therefore, gives valuable evidence regarding its constitution.

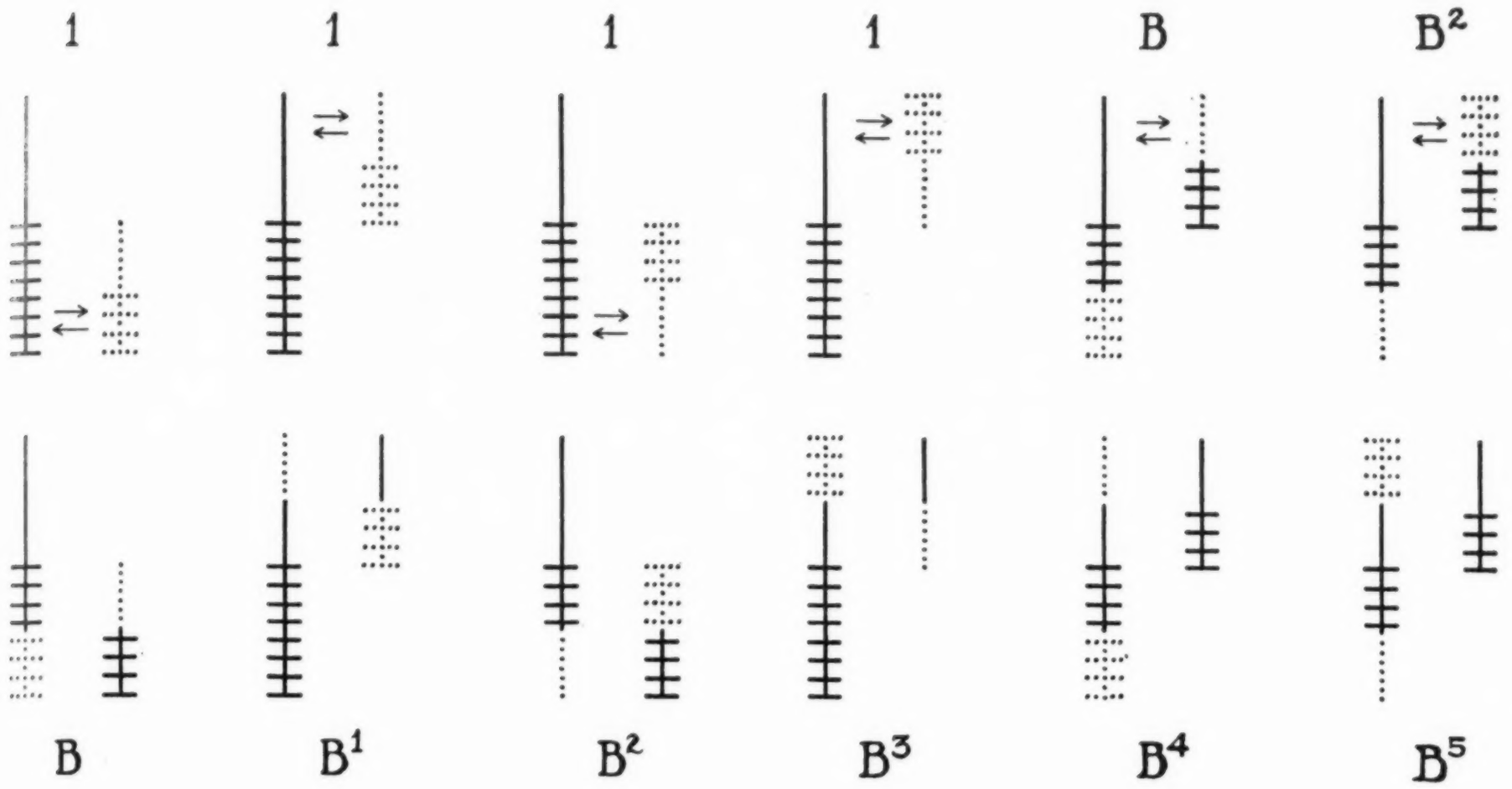
We need not discuss all the relations between these 13 theoretically possible types of chromosomes and the methods of distinguishing them. It is of interest, however, to discover whether the compositions assigned in the models to the *L* and *m* chromosomes of the *B* race we have particularly investigated are the only ones possible. We believe this to be the case especially from the morphological appearance of the type Wiry which has an extra *m* chromosome from the *B* race and shows certain characters brought about by factors in the – end of the stippled chromosome. The question whether more than one type of interchange between the *L* and *m* chromosomes has occurred in the origin of races in our collection is being investigated.

For convenience, we have spoken of the interchange as having involved one-half of the smaller chromosome and a corresponding length of the larger chromosome. We know that the segmental interchange has not visibly changed the size of the chromosomes involved, but neither the cytological evidence nor that from the morphological effects of extra chromosomes will warrant us as yet in assigning definite lengths to the parts which have interchanged. In all cases, however, it is safe to speak of similarity of the ends of chromosomes which are attached.

It may be stated that we have evidence, from configurations of three new (2n + 1) types worked out by Dr. Bergner as well as from their resemblance to known extra chromosomal forms, that chromosomal interchanges involving several different chromosomes have been taking place in our standard Line 1 since it was brought into cultivation. Types produced by extra chromosomes which have undergone segmental interchange between *non-homologous* chromosomes, we have called tertiary types in distinction from secondaries in which the extra chromosome has been formed by segmental interchange between two *homologous* chromosomes in such a way as to produce a chromosome with two similar ends. Primaries are types with an unmodified extra chromosome like the other two in the set affected.

Pollen Abortion in Hybrids

Although hybrids between our standard Line 1 and *B* races do not produce an unusual amount of pollen abortion, hybrids between certain other races do. Thus hybrids between Lines 1 and 7 have 50 per cent of their pollen grains and ovules aborted and these two lines have been used in a series of tests the



TYPES PRODUCED BY CHROMOSOMAL INTERCHANGE

Figure 32

Diagrams showing 13 different kinds of *L* and *m* chromosomes that might be expected if the end segments of these two chromosomes are capable of interchanging places. The *L* and *m* chromosomes of the standard Line 1 are represented respectively by solid and dotted lines. In the upper row are shown the chromosomes which are supposed to have interchanged their segments as indicated by the arrows. In the lower row are shown the constitutions of the two chromosomes which result from the interchange.

results of which are shown in Table 2. Pollen types are also given in Table 1 for races which are classified on the basis of the chromosomal configurations which they induce. A race which has good pollen in its hybrids with Line 1 but induces 50 per cent abortion in hybrids with Line 7 is listed as a Line 1 pollen type and classified in the white column in the graphs. Similarly Line 7 pollen types give hybrids with good pollen when combined with Line 7 and induce 50 per cent abortion when combined with Line 1. Such types are represented by the black columns.

We believe the differences between the Line 1 and the Line 7 types which are responsible for the pollen abortion have been brought about by translocations or by segmental interchange such that configurations of four chromosomes do not occur. Without such configurations, we should expect in about half of the cases that the separation of the chromosomes would produce non-viable combinations like those shown in Figure 30. The evidence is not complete, but we think we know which two chromosomes have been affected.

It will be noted that the 50 per cent bad pollen inducers have been found in widely separated regions but that in no country are they the dominant type.

On the other hand, the 25 per cent bad pollen inducers are the only types, with one exception, among the purple-flowered (P) races on the west coast of South America. In Chile the white-flowered (W) races belong to the Line 1 pollen type. The cause of the 25 per cent abortion appears to be in some way connected with the chromosomes in the small circle of four which Peruvian races induce in hybrids with Line 1. This conclusion is based on trisomic ratios, linkage, and the morphology of (2n + 1) types thrown by the hybrids. The mechanism, however, which brings about the abortion of a quarter of the pollen grains has not yet been determined.

The races which we have been discussing, which induce special chromosomal configurations and definite proportions of pollen abortion in hybrids with other lines, have been called cryptic types since they do not show their peculiarities by any external sign. The present study has shown that, within the single species *Datura Stramonium,* cryptic types of different kinds are widespread in nature and that their origin is best explained by segmental interchange between non-homologous chromosomes.

That a similar process has been at work in the differentiation of species within the genus Datura is evident from species hybrids which show conditions of chromosomal attachments, found by Dr. Bergner, and of pollen abortion, found by Dr. Cartledge—of the same kind but more extreme than that found in hybrids between races within the single species. By using the various chromosomal types discovered in *Datura Stramonium* as testers with other species and with races extracted from hybrids between these species and our Line 1, it should be possible to learn more about the differences which separate the various species in the genus Datura.

The configurations and pollen abortion found in other groups of plants, notably in Oenothera, indicate that segmental interchange has not been confined to Datura. Cases are known in which a factor in one race is associated or linked with a particular group of factors, but in a second race the same factor is linked with another set of factors. The two linkage groups may represent two different chromosomes and the apparent shift of the factor from one chromosome to another seems best explainable by segmental interchange. This has been pointed out recently by Hakansson[6], who found circles of four attached chromosomes in hybrids between two such races in garden peas. That a condition exists in humans similar to that found in Daturas and peas is suggested by the fact that the factor for webbed fingers behaves in certain lines as if it were located in the sex chromosome while in other lines it appears to be located in other chromosomes.

We have discussed the effects of the presence of different extra chromosomes and of portions of chromosomes upon the adult characters within a highly inbred line of a single species and have thereby been able to learn something about the factors present in these chromosomes and in the parts of which they are composed. We have given evidence from the pollen abortion, and the chromosomal configurations induced in hybrids and from the characters of extra chromosomal types thrown by such hybrids that interchange of segments between non-homologous chromosomes has been frequent in nature and has given rise to geographical races. We have shown that segmental interchange must have played a part in the differentiation of species in the genus Datura. We are able to begin to speak of the evolution of chromosomes. Ultimately it may be possible to learn the mechanisms of the evolution of species.

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